AD-A105 476 WOODWARD-CLYDE CONSULTANTS CHICAGO IL F/G 13/13
NATIONAL DAM SAFETY PROGRAM. WHALEY-SCOTT MINE DAM (MO 31155). --ETC(U)
DEC 80 R C BERGGREEN, L M KRAZYNSKI DACW43-80-C-0066

UNCLASSIFIED NL

1 OF 1
AD A
105476

END
DATE
FILMED
11-81
DTIC

LEVEL II

# MISSISSIPPI-KASKASKIA-ST. LOUIS BASIN

AD A105476

WHALEY-SCOTT MINE DAM
WASHINGTON COUNTY, MISSOURI
MO 31155

# PHASE 1 INSPECTION REPORT
# NATIONAL DAM SAFETY INSPECTION

United States Army
Corps of Engineers
...Serving the Army
...Serving the Nation

St. Louis District

DTIC
ELECTE
OCT 13 1981
S E

"Original contains color plates: All DTIC reproductions will be in black and white"

PREPARED BY: U.S. ARMY ENGINEER DISTRICT, ST. LOUIS

FOR: STATE OF MISSOURI

This document has been approved for public release and sale; its distribution is unlimited.

DECEMBER 1980

FILE COPY

81 10 9 023

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

| REPORT DOCUMENTATION PAGE | | READ INSTRUCTIONS BEFORE COMPLETING FORM |
|---|---|---|
| 1. REPORT NUMBER | 2. GOVT ACCESSION NO. AD-A105 | 3. RECIPIENT'S CATALOG NUMBER 476 |
| 4. TITLE (and Subtitle) Phase I Dam Inspection Report National Dam Safety Program Whaley-Scott Mine Dam (MO 31155) Washington County, Missouri | | 5. TYPE OF REPORT & PERIOD COVERED Final Report. |
| | | 6. PERFORMING ORG. REPORT NUMBER |
| 7. AUTHOR(s) Woodward-Clyde Consultants | | 8. CONTRACT OR GRANT NUMBER(s) DACW43-80-C-0066 |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Army Engineer District, St. Louis Dam Inventory and Inspection Section, LMSED-PD 210 Tucker Blvd., North, St. Louis, Mo. 63101 | | 10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 1365 |
| 11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Engineer District, St. Louis Dam Inventory and Inspection Section, LMSED-PD 210 Tucker Blvd., North, St. Louis, Mo. 63101 | | 12. REPORT DATE December 1980 |
| | | 13. NUMBER OF PAGES Approximately 60 |
| 14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) National Dam Safety Program. Whaley-Scott Mine Dam (MO 31155), Mississippi - Kaskaskia - St. Louis Basin, Washington County, Missouri. Phase I Inspection Report. | | 15. SECURITY CLASS. (of this report) UNCLASSIFIED |
| | | 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE |

16. DISTRIBUTION STATEMENT (of this Report)

Approved for release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Dam Safety, Lake, Dam Inspection, Private Dams

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report was prepared under the National Program of Inspection of Non-Federal Dams. This report assesses the general condition of the dam with respect to safety, based on available data and on visual inspection, to determine if the dam poses hazards to human life or property.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

411492 UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

DEPARTMENT OF THE ARMY
ST. LOUIS DISTRICT, CORPS OF ENGINEERS
210 TUCKER BOULEVARD, NORTH
ST. LOUIS, MISSOURI 63101

REPLY TO
ATTENTION OF

LMSED-P

SUBJECT: Whaley-Scott Mine Dam Phase I Inspection Report

This report presents the results of field inspection and evaluation of the Whaley-Scott Mine Dam (MO 31155).

It was prepared under the National Program of Inspection of Non-Federal Dams.

This dam has been classified as unsafe, non-emergency by the St. Louis District as a result of excessively steep downstream embankment slopes and erosion along the toe of the downstream embankment.

It should be noted that the length of the downstream damage zone has been estimated assuming that the impounded tailings are in a liquid state. Further investigation would be required to determine the actual state of the tailings. Such an investigation is beyond the scope of a Phase I study.

SUBMITTED BY: SIGNED — Chief, Engineering Division — 27 FEB 1981 Date

APPROVED BY: SIGNED — Colonel, CE, District Engineer — 27 FEB 1981 Date

Accession For
NTIS GRA&I X
DTIC TAB
Unannounced
Justification
By
Distribution/
Availability Codes
Dist | Avail and/or Special
A

**WHALEY-SCOTT MINE DAM**

Washington County, Missouri

Missouri Inventory No. 31155

**Phase I Inspection Report**

**National Dam Safety Program**

Prepared by

**Woodward-Clyde Consultants**

Chicago, Illinois

Under Direction of

St Louis District, Corps of Engineers

for

Governor of Missouri

December 1980

## *PREFACE*

*This report is prepared under guidance contained in the Recommended Guidelines for Safety Inspection of Dams for Phase I Investigations. Copies of these guidelines may be obtained from the Office of the Chief of Engineers, Washington, D. C., 20314. The purpose of a Phase I investigation is not to provide a complete evaluation of the safety of the structure nor to provide a guarantee on its future integrity. Rather the purpose of the program is to identify potentially hazardous conditions to the extent they can be identified by a visual examination. The assessment of the general condition of the dam is based upon available data (if any) and visual inspections. Detailed investigations, testing, and detailed computational evaluations are beyond the scope of a Phase I investigation; however, the investigation is intended to identify the need for more detailed studies. In view of the limited nature of the Phase I studies no assurance can be given that all deficiencies have been identified.*

*In reviewing this report, it should be realized that the reported condition of the dam is based on observations of field conditions at the time of inspection along with any data which may be available to the inspection team. In cases where the reservoir was lowered or drained prior to inspection, such action removes the normal load on the structure, as well as the reservoir head along with seepage pressures, and may obscure certain conditions which might otherwise be detectable if inspected under the normal operating environment of the structure.*

*It is important to note that the condition of a dam depends on numerous and constantly changing internal and external conditions, and is evolutionary in nature. It would be incorrect to assume that the present condition of the dam will continue to represent the condition of the dam at some point in the future. Only through frequent inspections can unsafe conditions be detected, so that corrective action can be taken. Likewise continued care and maintenance are necessary to minimize the possibility of development of unsafe conditions.*

PHASE I REPORT
NATIONAL DAM SAFETY PROGRAM

| | |
|---|---|
| Name of Dam | Whaley-Scott Mine Dam |
| State Located | Missouri |
| County Located | Washington |
| Stream | Unnamed Tributary of Old Mines Creek |
| Date of Inspection | 16 August 1980 |

Whaley-Scott Mine Dam, Missouri Inventory Number 31155, was inspected by Richard Berggreen (engineering geologist), Leonard Krazynski (geotechnical engineer), and Sean Tseng (hydrologist).

The dam inspection was made following the guidelines presented in the "Recommended Guidelines for Safety Inspection of Dams". These guidelines were developed by the Chief of Engineers, U.S. Army, Washington, D.C., with the help of federal and state agencies, professional engineering organizations, and private engineers. The resulting guidelines are considered to represent a consensus of the engineering profession. These guidelines are intended to provide for an expeditious identification, based on available data and a visual inspection, of those dams which may pose hazards to human life or property. In view of the limited nature of the study, no assurance can be given that all deficiencies have been identified.

Whaley-Scott Mine Dam is in the intermediate size classification based on its height of 79 ft and storage volume of 1141 ac-ft. The criteria for the intermediate size classification are: height between 40 and 100 ft or storage volume between 1,000 and 50,000 ac-ft.

The St Louis District, Corps of Engineers (SLD), has classified this dam as having a high hazard potential; we concur with the classification. The SLD estimated hazard zone length extends approximately two miles downstream of the dam. Within this zone are at least six permanent or vacation homes, a state highway and a gravel plant. The loss of life and property could be significant in the event of sudden dam failure.

The visual inspection and evaluation of available information indicate the dam is in less than fair condition. This evaluation is based on the potential for erosion along the discharge channel, where a breach of the embankment occurred in 1973, potential for erosion at the toe of the maximum section, where evidence of slumping and oversteepened slopes were noted, the obstructed condition of the main spillway and discharge channel and the inability to pass 100 percent of the Probable Maximum Flood (PMF) flood without overtopping parts of the embankment.

Hydraulic and hydrologic analyses indicate the spillway is capable of passing the 1 percent probability-of-occurrence flood (100 year flood) without overtopping the embankment. These analyses further indicate that a storm greater than 69 percent of the Probable Maximum Flood (PMF) will overtop the embankment. The PMF is defined as the flood event that may be expected to occur from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region.

Based on our inspection of the Whaley-Scott Mine Dam, it is recommended that further study be conducted, without undue delay, to evaluate as a minimum:

1. Methods to re-activate the auxiliary spillway and discharge channel at the clearwater pond or some alternative method to safely pass 100 percent of the PMF without overtopping the dam. A desirable objective would be to distribute and, if possible, approximately equalize the outflows through the main and auxiliary spillways at high flood stages. Erosion protection may be necessary for the auxiliary spillway design recommendations.

2. Methods to control and remove vegetation from the main spillway and discharge channel. Removal of trees from the embankment should be performed under the guidance of an engineer experienced in the design and maintenance of tailings dams. Indiscriminate clearing of large trees could jeopardize the safety of the dam.

3. Methods to control erosion of the southwestern embankment adjacent to the main discharge channel, particularly in the vicinity of a former breach in 1973.

4. Methods to control erosion during high flows at the foot of the waterfall near the toe of the maximum section.

5. Seepage and stability analyses should be performed by a professional engineer experienced in the design and construction of tailings dams.

It is also recommended that a program of periodic inspections and maintenance be established for this facility. This program should include, but not be limited to:

1. Monitoring spring activity near the toe of the dam to identify evidence of turbidity in the spring discharge.

2. Inspection of the embankment for evidence of erosion, slumping, cracking, or settlement.

3. Control of motorcycle traffic (if possible), to reduce surface erosion in heavily trafficked areas.

All remedial measures should be performed by an engineer experienced in the design and construction of tailings dams.

It is suggested that the owner takes action on these recommendations without undue delay to preclude deterioration which could lead to the development of hazardous conditions at this facility.

WOODWARD-CLYDE CONSULTANTS

Richard G. Berggreen
Registered Geologist

Leonard M. Krazynski, P.E.
Vice President

# OVERVIEW

# WHALEY-SCOTT MINE DAM

**MISSOURI INVENTORY NUMBER 31155**

PHASE I INSPECTION REPORT

NATIONAL DAM SAFETY PROGRAM

WHALEY-SCOTT MINE DAM, MISSOURI INVENTORY NO. 31155

TABLE OF CONTENTS

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM
WHALEY-SCOTT MINE DAM, MISSOURI INVENTORY NO. 31155

# SECTION 1
# PROJECT INFORMATION

## 1.1 General

a. **Authority.** The National Dam Inspection Act, Public Law 92-367, provides for a national inventory and inspection of dams throughout the United States. Pursuant to the above, an inspection was conducted of the Whaley-Scott Mine Dam, Missouri Inventory Number 31155.

b. **Purpose of inspection.** "The primary purpose of the Phase I investigation program is to identify expeditiously those dams which may pose hazards to human life or property... The Phase I investigation will develop an assessment of the general condition with respect to safety of the project based upon available data and a visual inspection, determine any need for emergency measures and conclude if additional studies, investigations and analyses are necessary and warranted" (Chapter 3, "Recommended Guidelines for Safety Inspection of Dams").

c. **Evaluation criteria.** The criteria used to evaluate the dam were established in the "Recommended Guidelines for Safety Inspection of Dams", Engineering Regulation No. 1110-2-106 and Engineering Circular No. 1110-2-188, "Engineering and Design National Program for Inspection of Non-Federal Dams," prepared by the Office of Chief of Engineers, Department of the Army, and "Hydrologic/Hydraulic Standards Phase I Safety Inspection of Non-Federal Dams" prepared by the St Louis District, Corps of Engineers. These guidelines were developed with the help of several federal agencies and many state agencies, professional engineering organizations and private engineers.

## 1.2 Description of Project

a. **Description of dam and appurtenances.** Whaley-Scott Mine Dam is an abandoned barite tailings dam. Although its construction and usage is typical of other barite tailings dam in the area, it is atypical of dams constructed to impound water. The unique nature of tailings dams has a significant impact on their evaluation. A brief description of their construction and usage is necessary to appreciate the differences between this dam and a conventional water-retaining dam.

At the start of a barite mining operation in this area, a 10 to 20-ft high starter dam is typically constructed across a natural stream channel. Generally the streams are intermittent so that construction is carried out in the dry. Trees and other vegetation are removed from the dam site and a cutoff is often made to shallow bedrock. Locally obtained earth, usually a gravelly clay, is then placed to form the embankment. Compaction is limited to that provided by the equipment.

The barite ore is contained within the residual gravelly clay which is mined with earth-moving equipment. At the processing plant, the ore is washed to loosen and remove the soil. This water is obtained from the reservoir area behind the dam. The soil-laden wash water and water from other steps in the process is then discharged into the reservoir. There the soil is deposited by sedimentation and the water recycled. Another step in the process removes the broken gravel-sized waste which is called "chat".

As the level of the fine tailings increases, the dam is raised. The usual method is to place chat, by dumping, on the dam crest. Then the chat is spread over the crest so that a relatively constant crest width is maintained as the dam is raised. Generally the crest centerline location is also maintained. However, the crest centerline location may migrate upstream if there is insufficient chat available and downstream if an excessive quantity of chat is available. The latter is uncommon because it is indicative of a poor ore deposit.

This method of construction results in slopes which are close to the natural angle of repose for the chat. They can be considered to be near a state of incipient failure.

A large quantity of water is required for a processing operation, on the order of 2000 to 5000 gal/min. Thus, it has been the operators' practice to construct the dam so that all inflow to the reservoir is recycled in order to have sufficient water for the operation, the result being that formal spillways or regulating outlets are generally not constructed. In most cases a low point on or near the dam is provided should the storage capacity be exceeded.

The fine tailings typically fill more than 80 percent of the total storage volume. This results from the operator's practice of maintaining only a 2 to 5 ft elevation differential between the level of the tailings and the dam crest. The differential is usually greater further away from the discharge point and also typically farther away from the dam.

The geotechnical characteristics of the fine tailings are somewhat similar to recent lacustrine clay deposits. Where the tailings have been continuously submerged, they have a very soft consistency and high water content. When evaporation causes the water level to recede and the tailings are exposed, a stiff crust forms as the tailings dry out. Below the crest, the tailings retain their soft consistency for long periods of time. This consistency is gradually modified by a slow process of consolidation.

Whaley-Scott Mine Dam is representative of barite tailings dams. The embankment is composed of chat. The downstream slope is very steep and the upstream slope is covered by the fine tailings. There are no regulating outlets. A formal spillway has not been constructed. Flow from the reservoir passes through a low area near the southwest end of the dam, into a low gradient discharge channel along the west edge of the impoundment which ends in a waterfall on exposed bedrock near the toe of the dam. Dimensions are presented in Section 1.3. A sketch of the operations layout is presented on Fig A-1, Appendix A.

b. **Location.** The dam is located approximately 10 miles north of the town of Potosi, Washington County, Missouri, just east of Highway 21, on an unnamed tributary of Old Mines Creek. The dam is in Section 29, T39N, R3E, on the USGS Tiff 7.5-minute quadrangle map.

c. **Size classification.** The dam is classified intermediate size, based on its approximate 79 ft height, and 1141 ac-ft storage. The intermediate size classification includes dams from 40 to 100 ft in height, or having storage capacities from 1000 to 50,000 ac-ft.

d. **Hazard classification.** The St Louis District, Corps of Engineers (SLD) has classified the dam as having a high hazard potential; we concur with this classification. The SLD estimated damage zone length extends approximately two miles downstream of the dam. There are at least six occupied or vacation home structures, a Missouri State Highway and a gravel plant within the estimated damage zone. As a result the potential for loss of life and property may be high in the event of sudden dam failure.

e. **Ownership.** The dam is reported to be owned by Mr John Higginbotham, Jr., Potosi Abstract Company, 106 E. High Street, Potosi, Missouri, 63664. Correspondence should be addressed to Mr Higginbotham.

f. **Purpose of dam.** The dam was constructed to impound fine barite tailings produced by washing of barite ore mined in the area. Water containing the tailings was discharged into the reservoir where the tailings settled out. Clear water was then recycled to the processing plant. At present, the dam is abandoned.

g. **Design and construction history.** Information on the design and construction history was obtained from interviews with Mr Joe Rossier, Milchem, Inc, former owners and operators of the plant and dam, and from Mr John Higginbotham, Sr., father of the present owner of the dam. The majority of information on construction was obtained from Mr Rossier.

No formal design was prepared for the dam. It was constructed using typical methods for the dams in the area. A 25 to 30 ft high starter dam of compacted earth was keyed to bedrock. The upstream slope was described as 3(H) to 1(V); the downstream slope was described as 2(H) to 1(V). The dam was raised by dumping bullrock and chat on the downstream face and depositing fines and clay on the upstream face. The dam was constructed with two tiers, the lower tier consisting of the starter dam, bullrock and chat, the upper tier of only chat. A road runs across the face of the dam on the flat bench between the two tiers.

Operations began at the mill and dam in approximately 1945 and were terminated in 1973. No additional construction has apparently been done at this dam since operations ended in 1973.

h. Normal operating procedures. The dam is currently abandoned and no operating procedures exist at this dam.

## 1.3 Pertinent Data

a. **Drainage area.** 1.15 $mi^2$

b. **Discharge at damsite.**

| | |
|---|---|
| Maximum known flood at damsite | Unknown |
| Warm water outlet at pool elevation | N/A |
| Diversion tunnel low pool outlet at pool elevation | N/A |
| Diversion tunnel outlet at pool elevation | N/A |
| Gated spillway capacity at pool elevation | N/A |
| Gated spillway capacity at maximum pool elevation | N/A |
| Ungated spillway capacity at maximum pool elevation | 2720 $ft^3$/sec |
| Total spillway capacity at maximum pool elevation | 2720 $ft^3$/sec |

c. **Elevation (ft above MSL).**

| | |
|---|---|
| Top of dam | 689.6 to 701.0 |
| Maximum pool-design surcharge | N/A |
| Full flood control pool | N/A |
| Recreation pool | N/A |
| Spillway crest (gated) | N/A |
| Upstream portal invert diversion tunnel | N/A |
| Downstream portal invert diversion tunnel | N/A |
| Streambed at centerline of dam | Unknown |

| | |
|---|---|
| Streambed at toe of maximum section | 622 |
| Maximum tailwater | N/A |

d. <u>Reservoir</u>.

| | |
|---|---|
| Length of maximum pool | 3800 ft |
| Length of recreation pool | N/A |
| Length of flood control pool | N/A |

e. <u>Storage (acre-feet)</u>.

| | |
|---|---|
| Recreation pool | N/A |
| Flood control pool | N/A |
| Design surcharge | N/A |
| Top of dam | 1141 (includes fine tailings) |

f. <u>Reservoir surface (acres)</u>.

| | |
|---|---|
| Top of dam | 53 |
| Maximum pool | 53 |
| Flood-control pool | N/A |
| Recreation pool | N/A |
| Spillway crest | 47 |

g. <u>Dam</u>.

| | |
|---|---|
| Type | Tailings |
| Length | 3234 ft |
| Height | 79 ft |
| Top width | 10 to 15 ft |
| Side slopes | Downstream face ranges from 1.4 - 2.6(H) to 1(V). Upstream unknown |
| Zoning | Unknown (probably none) |
| Impervious core | Unknown (probably none) |
| Cutoff | Reported to be shallow trench to bedrock (Mr Rossier) |

| | |
|---|---|
| Grout curtain | Unknown (probably none) |

h. **Diversion and regulating tunnel.**

| | |
|---|---|
| Type | None |
| Length | N/A |
| Closure | N/A |
| Access | N/A |
| Regulating facilities | N/A |

i. **Spillway.**

| | |
|---|---|
| Type | Unlined low area at southwest end of dam |
| Length of weir | Approximately 100 ft |
| Crest elevation | 682 ft |
| Gates | None |
| Upstream channel | None |
| Downstream channel | Unlined soil and tailings, some exposed rock. |

j. **Regulating outlets.** None

# SECTION 2
# ENGINEERING DATA

## 2.1 Design

No design drawings or data were found.

## 2.2 Construction

No construction records were found. Construction was likely typical of tailings dams in the area, according to a representative of the former owners and operators, Mr Rossier of Milchem, Inc. Typical construction practices are described in Section 1.2a.

## 2.3 Operation

No operation records are known to exist.

## 2.4 Evaluation

a. **Availability.** No engineering data were available for this dam.

b. **Adequacy.** The available information is insufficient to properly evaluate the design of the Whaley-Scott Mine Dam.

Seepage and stability analyses comparable to the requirements of the guidelines are not on record. This is a deficiency which should be rectified. These seepage and stability analyses should be performed for appropriate loading conditions (including earthquake loads) and made a matter of record. These analyses should be performed by an engineer experienced in the design and construction of tailings dams.

c. **Validity.** Not applicable.

## 2.5 Project Geology

The dam site lies on the northern flank of the Ozark structural dome. The regional dip is to the north. The bedrock in the area is mapped as Cambrian age Eminence and Potosi domomite formations on the *Geologic Map of Missouri* (Fig 4). The Potosi Formation is a light gray, medium- to fine-grained dolomite that typically contains an abundance of quartz druse characteristic of chert-bearing formations. The Eminence Formation conformably overlies the Potosi Formation, is generally similar in appearance but contains less quartz and chert. Large caves and springs have been located in the Eminence Formation in some portions of Missouri but no evidence of solution activity was noted at this site during the field inspection. One moderate size spring flowing approximately 10 to 20 gal/min was noted near the toe of the maximum section.

The soil at the dam site is a dark red-brown, plastic residual clay, (CH), characteristically developed on the Potosi Formation. It is locally overlain by a 1 to 5 ft thick silty loess soil profile (ML). The area is mapped on the Missouri General Soils Map as Union-Goss-Gasconade-Peridge Association.

The Cruise Mill-Fertile Fault Zone is mapped on the Structural Features Map of Missouri about 1 mile northeast of the dam. The fault zone is mapped as approximately 6 miles long with a northwest-southeast trend. It may connect with the Richwoods Fault Zone further to the northwest for a total length of about 25 miles. Both faults are mapped as northeast side up.

These faults, like most others in the Ozark area, are likely Paleozoic in age, and are not in a seismically active area. They are not considered to pose a significant hazard to the dam.

# SECTION 3
# VISUAL INSPECTION

## 3.1 Findings

a. **General.** The dam was inspected on 16 August 1980 without the owners' representative present. This inspection indicated the dam is in less than fair condition.

b. **Dam.** The Whaley-Scott Mine Dam is a long "U" shaped embankment, with the upstream, or open end of the "U" pointing southeast. Discharge from the impoundment flows along the southwest side of the embankment. See Figure A-1, Appendix A, for a sketch of the layout of the operation.

At the maximum section the dam is constructed in two tiers. The lower tier is very steep, on the order of 34 to 36 degrees. This tier is constructed of material ranging in size from clay and sand to cobbles and boulders up to 2 ft in diameter (Photo 1). The toe of the slope is locally undercut by erosion in the discharge channel. Parts of the toe of the slope have a steepened slope inclination and some evidence of local small slides was noted during the field inspection.

The upper tier is constructed of chat, gravel-sized tailings (Photo 2). The slopes average about 30 degrees but are locally as steep as 35 degrees. This upper tier continues around the sides of the impoundment from the maximum section (see Fig A-1) Where this embankment is adjacent to the discharge channel on the southwest side of the impoundment, erosion has locally oversteepened the slope. From discussions with an employee of the previous owner of the dam (Mr Joe Rossier, Milchem, Inc), it was discovered that a breach occurred in this portion of the embankment in 1973. A discussion of this breach is presented in Section 6.1c.

The upper tier of the dam appears to have been extensively used by motorcycle riders (Photo 2 and Overview photo). In several locations on the crest of the dam, erosion has been concentrated into tracks worn by motorcycle and off-road vehicle traffic and gullies up to 5 ft deep have resulted.

No evidence of noticeable displacement of the vertical or horizontal alignment of the dam crest was noted, except in the location of the previously breached embankment. At this location material has been dumped to plug the breach. Cracking in the vicinity of the breached area (Photo 3) is described in Section 6.1c.

No evidence of sinkhole development or animal burrows was noted on the dam.

Erosion appeared limited to the toe of the southern arm of the embankment adjacent to the discharge channel, the toe of the maximum section, also adjacent to the discharge channel, and in the areas of heavy motorcycle and off-road vehicle traffic.

Seepage appeared very limited along much of the embankment. The presence of the discharge channel and relatively moist conditions resulting from heavy precipitation shortly before the inspection made identification of seepage difficult. One area of spring activity was located near the toe of the maximum section. Water was flowing to the surface at approximately 10 to 20 gal/min. This flow was clear and was not carrying any soil. It was very near the bedrock contact and felt colder than the reservoir temperature. It was thus attributed to spring activity rather than seepage.

c. **Appurtenant structures.** The main spillway for this dam consists of a broad low area at the southwest end of the embankment. The spillway is located between the southwest end of the embankment and a pushed-up dike of soil (Fig A-1, Appendix A). The spillway area is approximately 100 ft wide and is very heavily overgrown with small willow vegetation (Photo 4). This spillway area could become obstructed during heavy flood flows.

The materials comprising the end of the embankment and soil dike are likely erodible during high flows. Erosion of this main spillway area would enlarge the effective spillway. This, in turn, would result in heavier flows in the main discharge channel and would jeopardize the stability of the adjacent embankment slopes. There are no control structures in the spillway of this dam.

d. **Reservoir area.** The majority of the reservoir area is covered with a dense growth of willow (Photo 5). Two clearwater ponds, apparently separated from the main impoundment area by a baffle dike and a low mound of deposited tailings, are located along the northeast side of the reservoir (Photo 6). The main impoundment area is filled almost to the level of the crest of the dam with a nearly impervious deposit of fine tailings composed of sand, silt, and clay.

The slopes around the reservoir are relatively flat. No evidence of landslides or unstable slopes was noted during the field inspection.

e. **Discharge channel.** The main discharge channel runs along the southwestern side of the embankment from the spillway for about 2100 ft. Portions of this channel are densely vegetated and could become partially obstructed during flood flows (Photo 7).

The discharge channel runs along the toe of the embankment. The lower portions of the embankment slopes are densely vegetated in some areas, but the vegetation is not uniform.

The material comprising the embankment slopes appears relatively easily eroded. Gravel bars, indicating past erosion and deposition of embankment gravels, were noted in the discharge channel (Photo 9). The flat slope of the channel indicates erosion will likely be limited to periods of severe flooding and substantial discharges. A previous owner described a breach of the embankment in this area in 1972 or 1973 (see Section 6.1c). This breach may have been caused by erosion at the toe of the slope and subsequent sliding of the embankment.

At the northwest corner of the dam, the discharge channel flows between two vertical concrete walls remaining from a dismantled bridge for a road that used to cross the face of the dam. From this bridge, the channel turns northeast and flows down a rock falls approximately 40 ft high at the toe of the dam. Some erosion of the toe of the dam has occurred at the foot of the waterfall (Photo 10). Evidence of surface sloughing and portions of slopes as steep as 50 degrees were noted during the field inspection, probably the result of erosion and oversteepening.

At the time of our inspection (16 August 1980) the main discharge channel was flowing at an estimated rate of 20 to 30 $ft^3$/sec. This apparently resulted from a high intensity, but short duration rain in the early morning hours of the same day.

## 3.2 Evaluation

The dam embankment is composed of granular material that appears moderately to easily eroded in the event of overtopping. Significant erosion could cause a failure of this dam. Where the main discharge channel flows along the toe of the embankment some erosion of the toe could occur. A prior breach of the embankment which occurred in this area may have resulted from erosion at the toe and subsequent sliding of the embankment. Erosion was also noted at the foot of the waterfall near the toe of the maximum section. The proximity of this erosion to the maximum section and the evidence of small slumps noted during the field inspection indicate that this area should be more thoroughly evaluated to determine the stability of the slope and possible options for mitigating erosion in this area. The spillway and discharge channel are very densely vegetated and may become obstructed during flood flows.

Other than the area where the breach occurred, no evidence was found of displacement of the vertical or horizontal alignment of the dam. No sinkhole development or animal burrows were noted.

Surface erosion was noted where heavy motorcycle and off-road vehicle traffic had resulted in concentrating runoff, along the discharge channel, and near the toe of the dam.

An area of spring activity was noted at the bedrock contact near the toe of the maximum section. The flow was not carrying any soil and appeared to be a bedrock spring rather than seepage through the embankment.

# SECTION 4
# OPERATIONAL PROCEDURES

## 4.1 Procedures

The dam is currently abandoned and there are no formal operating procedures in effect for this dam.

## 4.2 Maintenance of Dam

No evidence of maintenance was identified at this dam.

## 4.3 Maintenance of Operating Facilities

No operating facilities exist at this dam which require maintenance.

## 4.4 Description of any Warning System in Effect

Our visual inspection did not identify any warning system in effect at this dam.

## 4.5 Evaluation

There is no formal plan for periodic inspection or performance of maintenance. This is considered a deficiency.

The feasibility of a practical warning system should be evaluated to alert downstream residents and traffic should potentially hazardous conditions develop at the dam during periods of heavy precipitation.

# SECTION 5
# HYDRAULIC/HYDROLOGIC

## 5.1 Evaluation of Features

a. Design data. No hydrologic or hydraulic design data was available to aid the evaluation of this dam or reservoir; however, dimensions of the embankment and discharge channel were field surveyed 31 July 1980. Other relevent data were measured during the visual inspection or estimated from topographic mapping. The map used for the analysis is the advance print USGS 7.5-minute Tiff, Missouri quadrangle sheet (1979).

b. Experience data. No recorded history of rainfall, runoff, discharge or pool stage data was found for this impoundment or its drainage area.

c. Visual inspection.

1. Watershed. Approximately 75 percent of the drainage basin consists of forest. The remainder of the watershed is composed of mined out areas and second growth forest and brush. The area of the impoundment is approximately 6 percent of the total drainage area of 1.15 square miles.

2. Reservoir. The reservoir and dam are best described by the maps and photographs enclosed herewith. The purpose for the reservoir was to impound tailings produced during the processing of the barite ore mined in the area. The mining operation has been shut down for approximately 7 to 8 years. One significant feature of the reservoir is that the pattern of deposition of the fine-grained tailings and/or subsequent vegetation growth have resulted in a low mound, or flat dike, within the reservoir. This area of comparatively small topographic rise is apparently capable of separating the clearwater pond from the main reservoir at low stages of flooding. At the time of our inspection, when the water in the main reservoir was just spilling over the crest of the main spillway (elevation 682), the water surface of the clearwater pond was observed to be about 2 to 3 ft above that elevation. Our observations indicate, however, that at higher stages of flooding, intercommunication will be established between the clearwater pond and the main reservoir.

3. Main Spillway. The unlined, approximately trapezoidal spillway is located at the end of the long southwestern side of the embankment. The spillway, as well as the discharge channel just downstream of it, are both overgrown by vegetation. The spillway could easily become partially obstructed during flood flows. The crest elevation of the main spillway is 682 ft. This is the only spillway that was considered active for our hydrology analyses of the existing conditions at this dam.

4. Auxiliary Spillway. An auxiliary spillway exists at the eastern side of the embankment at the northwest end of the clearwater pond. (See Fig A-1, Appendix A). The crest of this spillway has been raised with chat to elevation 691.2, which renders this spillway inoperative for the existing conditions (the low point on the dam crest is at el 689.2). However, with reconstruction and appropriate adjustment of crest elevation, this spillway does offer an opportunity for release of storm water. This is further discussed in Section 5.1d and Section 7.2b.

5. Discharge channel. Unlike most dams that have their embankments constructed across the valley in the most obvious and shortest-length configuration, Whaley-Scott Mine Dam was constructed in such a way as to form a long U-shaped embankment away from the valley sides. The main discharge channel begins at the end of the western (and longest) arm of the embankment, and flows along the toe of this portion of the dam for approximately 2100 ft, before dropping sharply to the original streambed. Near the junction with the original streambed the main discharge channel is constrained by vertical concrete walls, which are the remains of a dismantled bridge (Photo 11, Fig 3-B, and A-1). At this restricted point the channel is 15 ft wide and the concrete walls are 9 ft high. At the time of our inspection the main discharge channel was carrying a flow estimated at 20 to 30 $ft^3$/sec.

6. Auxiliary discharge channel. Downstream of the auxiliary spillway, there is a wide discharge channel, which appears to have carried prior flows from the clearwater pond (see Overview Photograph). Construction activity in this area has resulted in some surface irregularities and obstructions. These features will require some re-shaping if the auxiliary spillway is to be used in

the future. The auxiliary discharge channel empties into the same streambed as the main discharge channel. The confluence of these discharge channels is in a desirable location, downstream of the main dam embankment.

7. Seepage. The magnitude of seepage through this dam is not significant to the overtopping potential.

d. **Overtopping potential.** One of the primary considerations in the evaluation of Whaley-Scott Mine Dam is the assessment of the potential for overtopping and/or other modes of failure by erosion of the embankment.

Since the spillway is not lined, it is erodible at high flows; however, the configuration of this dam, with its spillway at the upstream end, provides a degree of safety. The present configuration of the embankment and reservoir indicate that nearly all of the inflow is passed over the spillway with little time lag. Only a small proportion of the runoff becomes temporarily stored. Furthermore, the slope of the fine-grained tailing surface will confine the bulk of the stored water to the upstream end of the impoundment, near the main spillway. The fact that the lowest portion of the dam embankment is on the western side, approximately 800 ft from the spillway, means that if the dam is overtopped, catastrophic outflow is not likely since the height of dam there is only about 15 feet. Nevertheless, a breach of this portion of the embankment would appear very likely in the event of significant overtopping and would be undesirable.

Hydrologic analyses of this impoundment for all storm events were based on starting water surface elevations equal to the existing main spillway crest which appears to be the elevation of the annual high water mark. The results of the hydraulic/hydrologic analyses indicate that a flood of greater than 69 percent of the Probable Maximum Flood (PMF) will effectively overtop the dam. The PMF is defined as the flood event that may be expected to occur from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region.

The following results were computed with the existing dam configuration for various flood events, assuming no erosion of the spillway:

| Percent PMF | Maximum Water Surface Elevation, ft (MSL) | Maximum Depth of Overtopping, ft | Maximum Outflow, $ft^3/sec$ | Duration of Overtopping, hrs |
|---|---|---|---|---|
| 50 | 688.5 | 0 | 1920 | 0 |
| 69 | 689.6 | 0 | 2720 | 0 |
| 70 | 689.6 | 0.02 | 2760 | 0.3 |
| 100 | 690.6 | 1.0 | 4300 | 3.0 |

Our evaluation of the flow quantities listed above indicates that the higher flows in the existing main discharge channel are undesirable. As was mentioned before, overtopping due to 100 percent of the PMF flood would very likely cause a breach in the southwestern portion of the dam. Also, even without overtopping, the flows of as much as 2700 $ft^3/sec$ (i.e., 69 percent of the PMF) would represent a serious potential erosion hazard at the toe of the embankment. As an example, at Section D-D (Fig 3-C) our analyses indicate that this flow would result in a water surface in the main discharge channel at elevation 684.2 with the flow velocity of over 8 ft/sec. This would cause extensive erosion and may threaten the stability of the slope.

In addition, the flow of 2700 $ft^3/sec$ will just be contained within the restricted section at the dismantled bridge (water surface elevation of 677.8) with flow velocity over 18 ft/sec. While the bottom of the channel is in rock in this location, it is noteworthy that any flows of higher volume would overtop the bridge concrete walls and would flow on soil (see Fig 3-B).

In view of the considerations discussed above, it is our opinion that flows in the main discharge channel should be minimized to the degree that is practically obtainable. As one available option, such a result can be accomplished by utilizing the auxiliary spillway and discharge channel. Additional hydrologic studies would be necessary to evaluate the feasibility and to establish the flood stage at which the auxiliary spillway and discharge channel would become operational. The objective of such studies would be to distribute and, if possible, approximately equalize outflows through the main and auxiliary spillways at high flood stages.

# SECTION 6
# STRUCTURAL STABILITY

## 6.1 Evaluation of Structural Stability

a. **Visual observations.** Features identified during the visual inspection which adversely affect the structural stability of this dam are reported in Section 3. Of primary importance are the steep downstream slope of the embankment and the potential for erosion at the toe of the dam during the periods of high flows.

b. **Design and construction data.** No design or construction data relating to the structural stability of the dam were found. Seepage and stability analyses comparable to the requirements of the guidelines are not on record. This is a deficiency which should be corrected to meet recommended guidelines.

c. **Operating records.** No appurtenant structures requiring operation exist at this dam.

From discussions with Mr Joe Rossier of Milchem, Inc, former owners and operators of the mine and dam, it was learned that a breach had occurred in the embankment shortly before operations were terminated, 1973. This breach occurred during a heavy thunderstorm. Mr Rossier said the fine-grained tailings did not flow out of the breach, but were eroded by the flowing water into a series of steps, suggestive of depositional layering. Mr Rossier estimated that 1000 $yd^3$ of fine-grained tailings were washed from the impoundment.

During the visual inspection, the area of the breach was inspected. The embankment in this area supports a dense growth of weeds and brush, indicating the materials may contain more fines to hold moisture. Northwest of the breached area, a crack was noted in the dam crest (Photo 3 and Fig A-1). The crack is offset down toward the impoundment, indicating slumping toward the impoundment. From examination of other failed tailings dams, it appears this crack may have resulted from erosion on the inside of the embankment by the flow of tailings toward and out of the breach. Although the breach has been filled and the area behind the dam is presently nearly filled with tailings, this crack suggests the dam has undergone some deformation and may be structually less stable in the vicinity of the breach. The height of the embankment in this area is 15 to 20 ft.

d. <u>Post construction changes.</u> The dam and reservoir have been abandoned for about 7 or 8 years. Use of the road crossing the face of the dam has been discontinued. Motorcycle traffic on the dam has resulted in localized erosion. No other changes were noted during the inspection.

e. <u>Seismic stability.</u> The dam is in Seismic Zone 2, to which the guidelines assign a moderate damage potential. Since no static stability analysis is available for review, the seismic stability cannot be evaluated. However, as the tailings are saturated and the dam is constructed of relatively loose, granular material, substantial deformation or failure could occur in the event of a severe seismic event.

# SECTION 7
# ASSESSMENT/REMEDIAL MEASURES

## 7.1 Dam Assessment

a. **Safety.** Based on the visual inspection and evaluation of the available data, the dam is judged to be in less than fair condition. This judgment is based on the potential for erosion at the toe near the maximum section of the dam and evidence of slumping and slope steepening in this area, potential for erosion by the discharge channel along the southwestern embankment and the record of a prior breach in this area, and on the dense vegetation in the spillway and discharge channel and potential for obstruction during flood flows. Seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dams" were not available, which is considered a deficiency.

As a consequence of the widely-used construction procedure, the slopes of the tailings dams are placed at the angle of natural repose for the material at any given operation. This results in slopes that are very steep and exist close to incipient failure with safety factors approximately equal to one. This situation is subject to some gradual improvement with time as consolidation and/or desiccation of the fine-grained tailings result in an increase in strength and a decrease in lateral pressures on the embankment.

The slopes placed at an angle of natural repose will only remain stable if they are protected against changes that increase loading or decrease strength. Such changes include, but may not be limited to, the following:

1. Overtopping by water,
2. Higher pore pressures (or seepage forces),
3. Undercutting of the toe of the slope by erosion or mining activity,
4. Increase in the height of the slope,
5. Liquefaction (such as may result from a seismic event).

The first four changes are partially subject to control by owners and operators and must receive careful attention in order to maintain stable and safe dam embankments. The fifth influence represents a risk the magnitude of which is not well understood without further study.

b. **Adequacy of information.** The lack of stability or seepage analyses for the dam as recommended in the guidelines preclude an evaluation of the structural and seismic stability of the dam.

c. **Urgency.** The deficiencies described in this report could affect the safety of the dam. Corrective actions should be initiated without undue delay.

d. **Necessity for Phase II.** In accordance with the "Recommended Guidelines for Safety Inspection of Dams", the subject investigation was a minimum study. This study revealed that additional in-depth investigations as described in Section 7.2b are needed to complete the assessment of the safety of the dam. It is our understanding from discussions with the St Louis District that these additional in-depth investigations are the responsibility of the owner.

## 7.2 Remedial Measures

a. **Alternatives.** There are several general options which may be considered to reduce the possibility of dam failure or to diminish the harmful consequences of such a failure. Some of these options are:

1. Remove the dam, or breach it to prevent storage of water.

2. Increase the height of dam and/or spillway size to pass the probable maximum flood without overtopping the dam.

3. Purchase downstream land that would be adversely impacted by dam failure and restrict human occupancy.

4. Provide a highly reliable flood warning system (generally does not prevent damage but minimizes the potential for loss of life).

b. Recommendations. Based on the inspection of the Whaley-Scott Mine Dam, it is recommended that further study be conducted, without undue delay, to evaluate as a minimum:

1. Methods to reactivate the auxiliary spillway and discharge channel at the clearwater pond or some alternative method to safely pass 100 percent of the PMF without overtopping the dam. A desirable objective would be to distribute and, if possible, approximately equalize the outflows through the main and auxiliary spillways at high flood stages. Erosion protection may be necessary for the auxiliary spillway design recommendation.

2. Methods to control and remove vegetation from the main spillway and discharge channel. Removal of trees from the embankment should be performed under the guidance of an engineer experienced in the design and maintenance of failings dams. Indiscriminate clearing of larger trees could jeopardize the safety of the dam.

3. Methods to control erosion of the southwestern embankment adjacent to the main discharge channel, particularly in the vicinity of a former breach in 1973.

4. Methods to control erosion during high flows at the foot of the waterfall near the toe of the maximum section.

5. Seepage and stability analyses should be performed by a professional engineer experienced in the design and construction of tailings dams.

c. O & M procedures. A program of periodic inspections and maintenance should be established for this facility. This program should include but not be limited to:

1. Monitoring spring activity near the toe of the dam to identify evidence of turbidity in the spring discharge.

2. Inspection of embankment for evidence of erosion, slumping, settlement or cracking.

3. Control of motorcycle traffic (if possible) to reduce surface erosion in heavily trafficked areas.

Reports of inspections and any necessary maintenance should be made a matter of record. All remedial work should be performed by an engineer experienced in the design and construction of tailings dams.

# REFERENCES


Allgood, Ferris P., and Persinger, Ivan, D., 1979, "Missouri General Soil Map and Soil Association Descriptions," US Department of Agriculture, Soil Conservation Service and Missouri Agricultural Experiment Station.

Department of the Army, Office of the Chief of Engineers, 1977, EC 1110-2-188, "National Program of Inspection of Non-Federal Dams".

Department of the Army, Office of the Chief of Engineers, 1979, ER 1110-2-106, "National Program of Inspection of Non-Federal Dams".

Hydrologic Engineering Center, US Army Corps of Engineers, 1978, "Flood Hydrograph Package (HEC-1) Users Manual for Dam Safety Investigations".

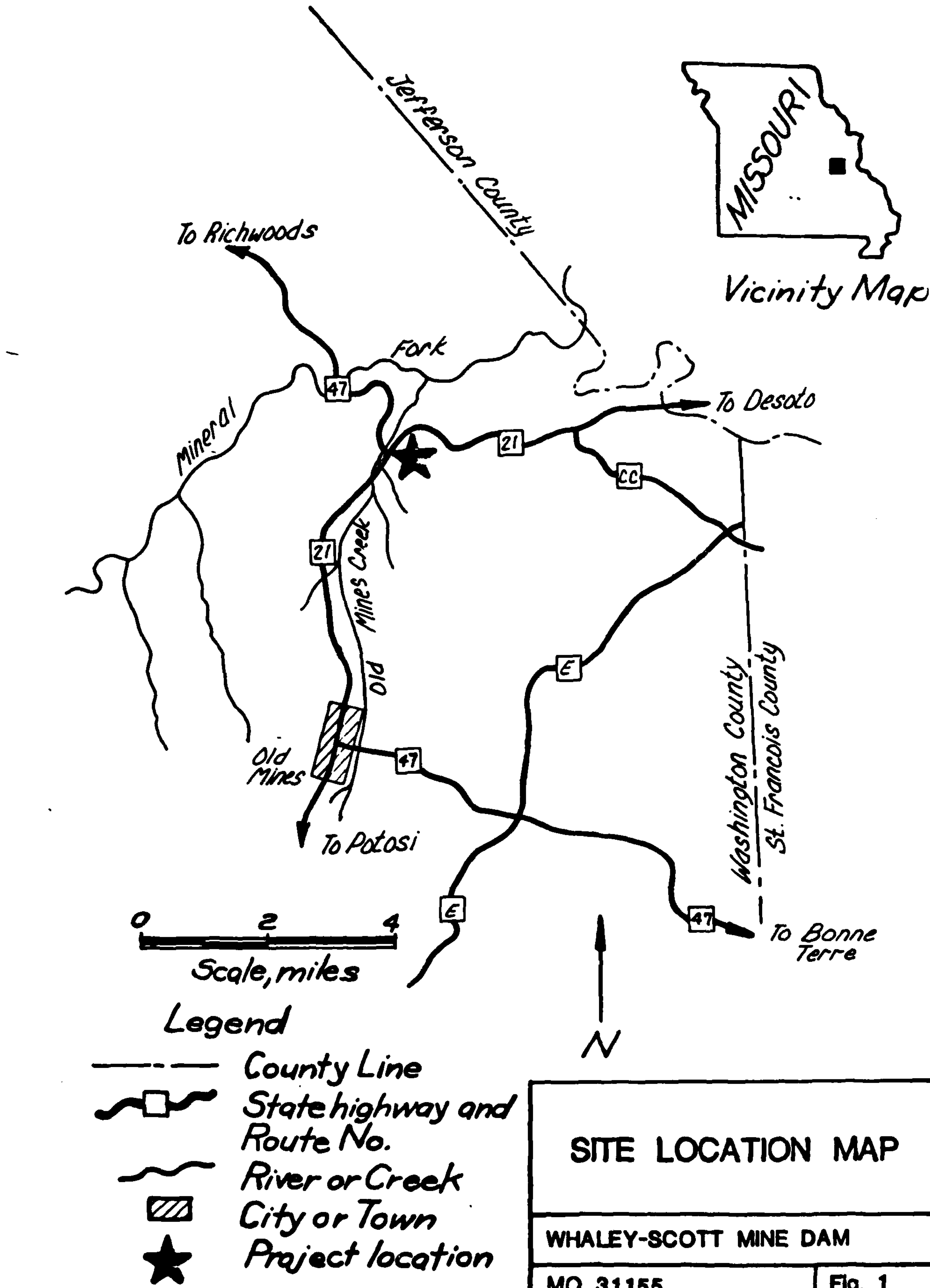
McCracken, Mary H., 1971, Structural Features Map of Missouri: Missouri Geological Survey, Scale 1:500,000.

Missouri Geological Survey, 1979, Geologic Map of Missouri: Missouri Geological Survey, Scale 1:500,000.

St Louis District, US Army Corps of Engineers, 1979, "Hydrologic/Hydraulic Standards, Phase I Safety Inspection of Non-Federal Dams".

US Department of Commerce, US Weather Bureau, 1956, "Seasonal Variation of the Probable Maximum Precipitation East of the 105th Meridian for Areas from 10 to 1,000 Square Miles and Durations of 6, 12, 24 and 48 Hours," Hydrometeorological Report No. 33.

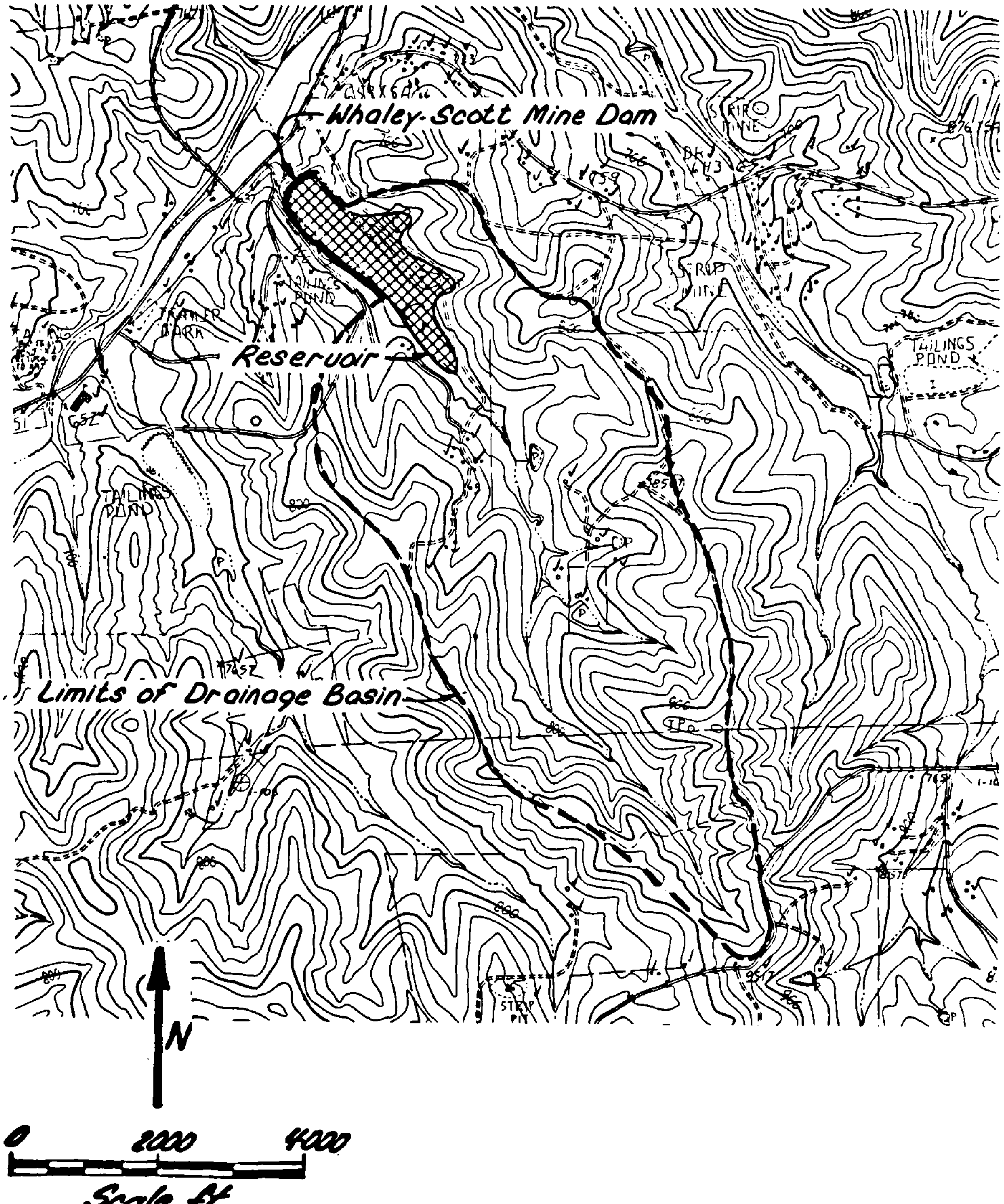
US Soil Conservation Service, 1971, "National Engineering Handbook," Section 4, Hydrology, 1971.




**SITE LOCATION MAP**

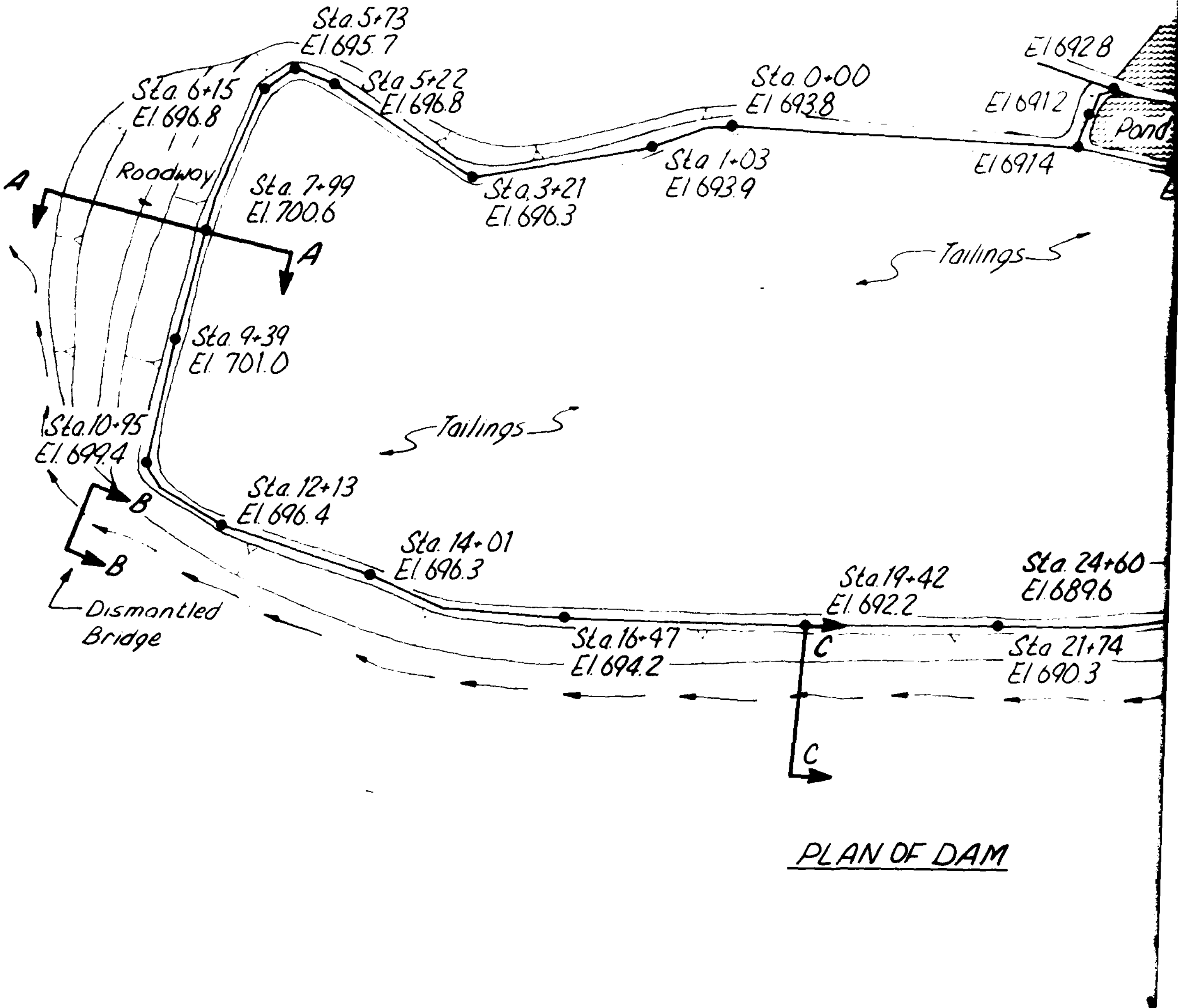
WHALEY-SCOTT MINE DAM

| | |
|---|---|
| MO 31155 | Fig. 1 |



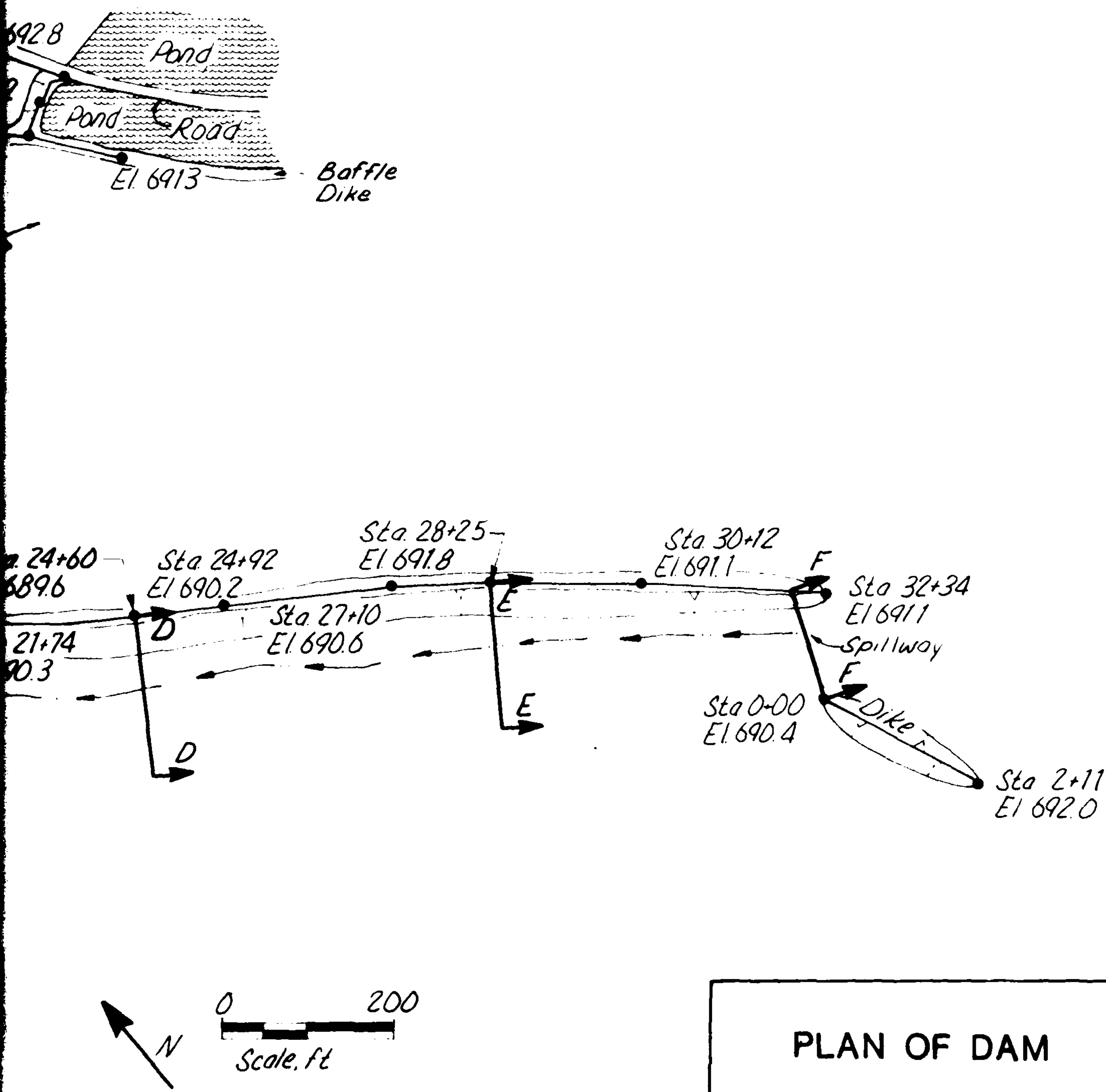

Note:
1. Topography from USGS Tiff 7½ minute quadrangle map.

| DRAINAGE BASIN AND SITE TOPOGRAPHY | |
|---|---|
| WHALEY-SCOTT MINE DAM | |
| MO 31155 | Fig. 2 |



Sta. 5+73
El. 695.7
Sta. 5+22
El. 696.8
Sta. 6+15
El. 696.8
Sta. 0+00
El. 693.8
El. 692.8
El. 691.2
Pond
El. 691.4
Roadway
Sta. 7+99
El. 700.6
Sta. 3+21
El. 696.3
Sta. 1+03
El. 693.9
A
A
Tailings
Sta. 9+39
El. 701.0
Tailings
Sta. 10+95
El. 699.4
B
B
Sta. 12+13
El. 696.4
Sta. 14+01
El. 696.3
Dismantled
Bridge
Sta. 19+42
El. 692.2
Sta. 24+60
El. 689.6
Sta. 16+47
El. 694.2
C
Sta. 21+74
El. 690.3
C


PLAN OF DAM

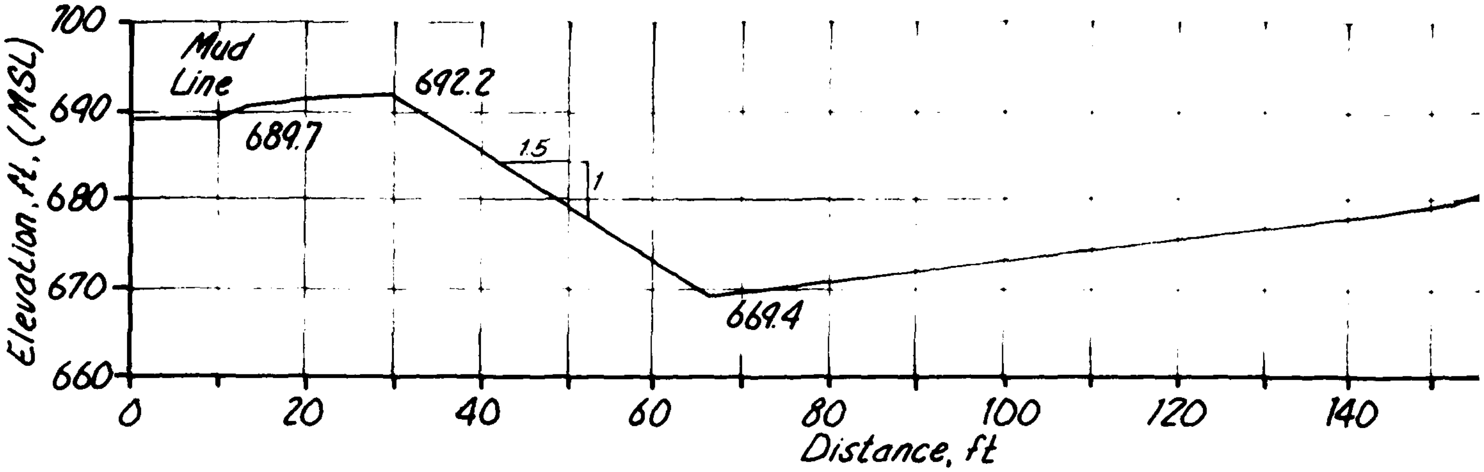



PLAN OF DAM

WHALEY-SCOTT MINE DAM

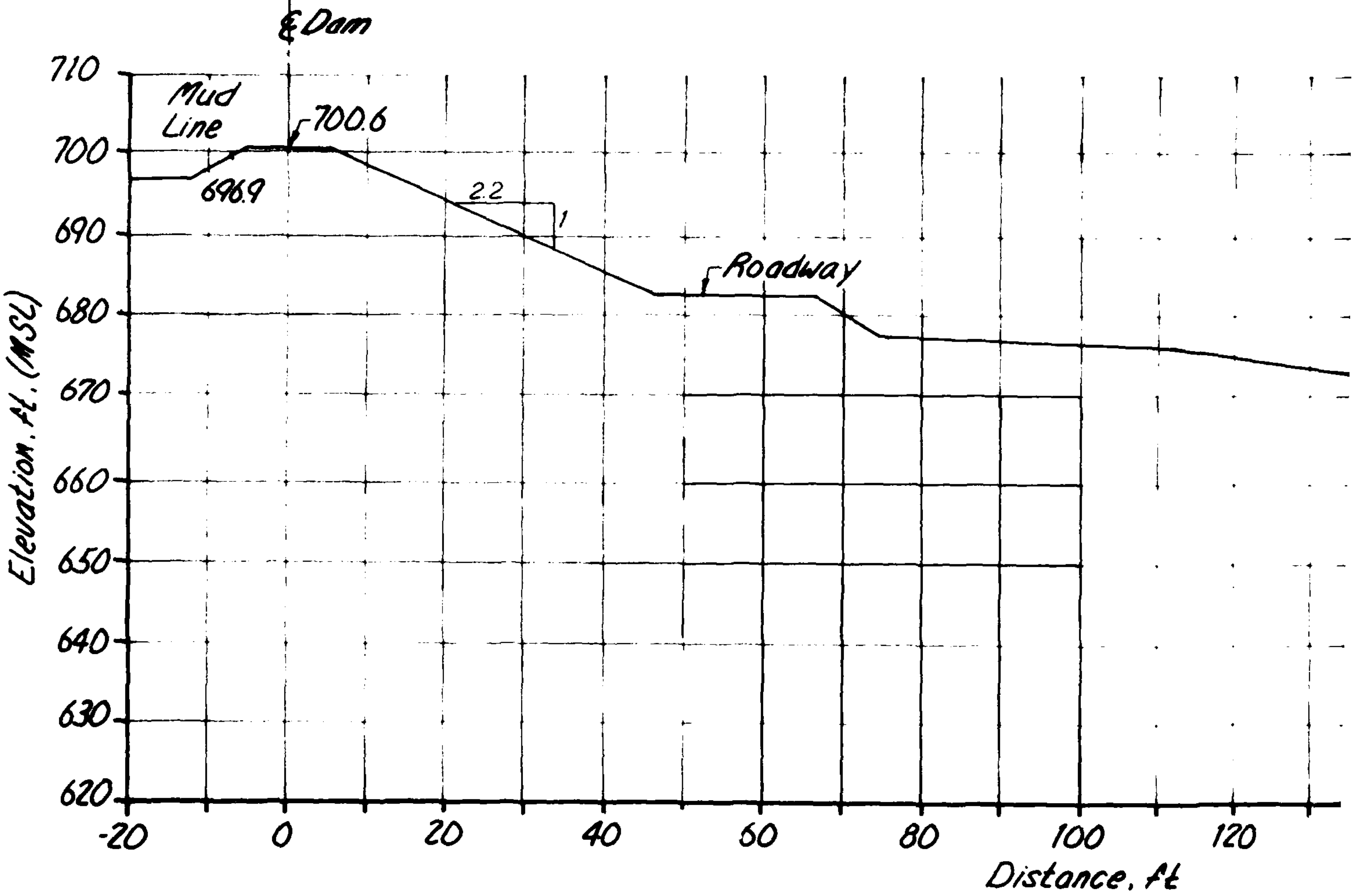
| | |
|---|---|
| MO 31155 | Fig.3-A |

2



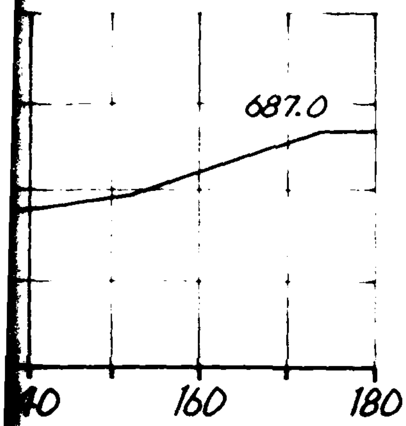

SECTION C-C

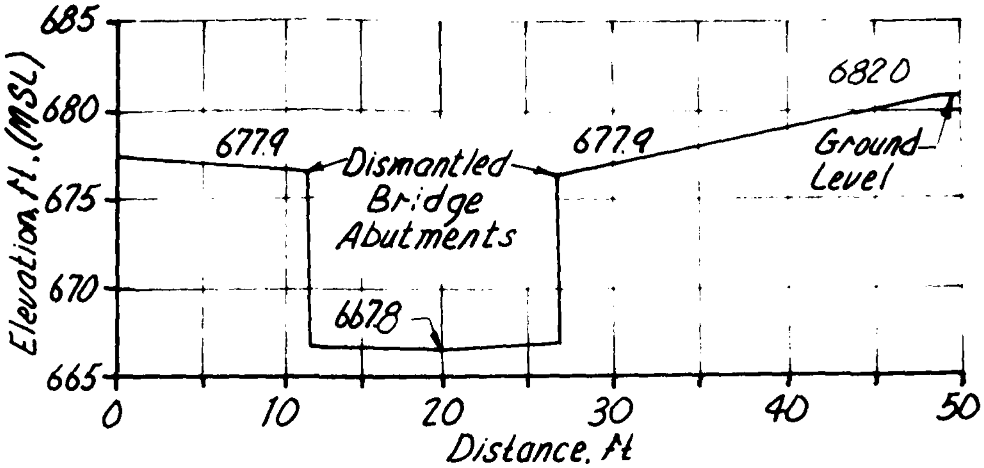
Discharge Channel




SECTION A-A

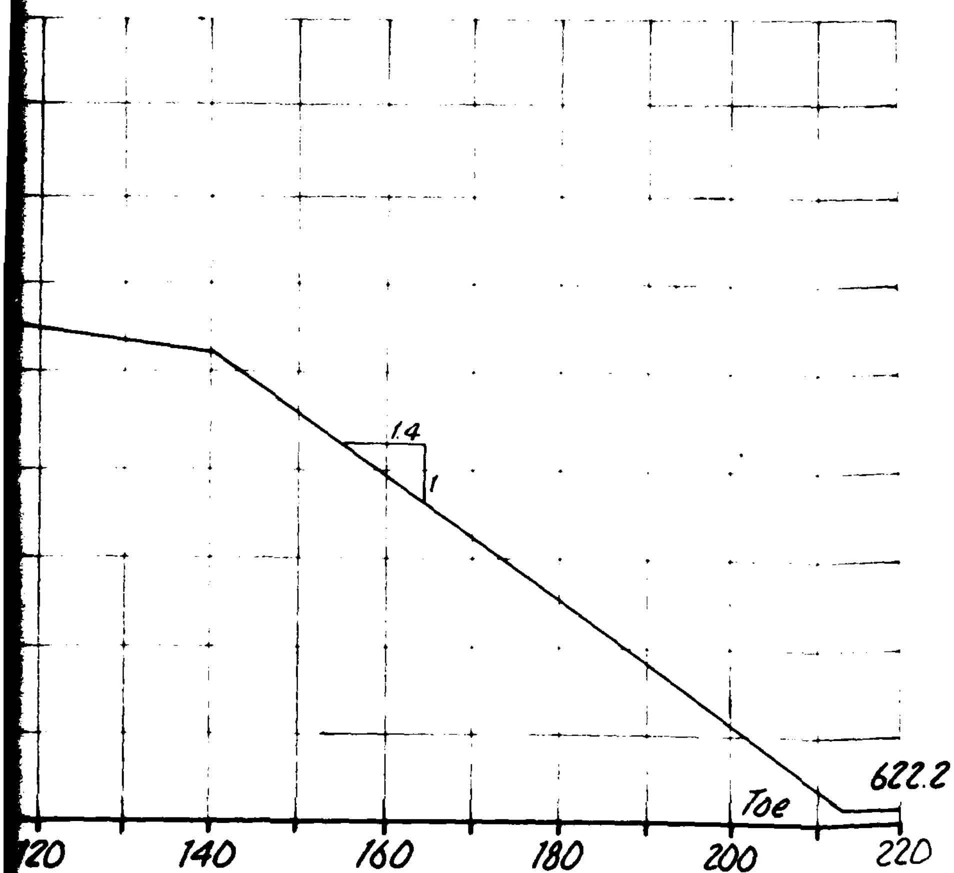
Maximum Section




SECTION B-B

Discharge Channel

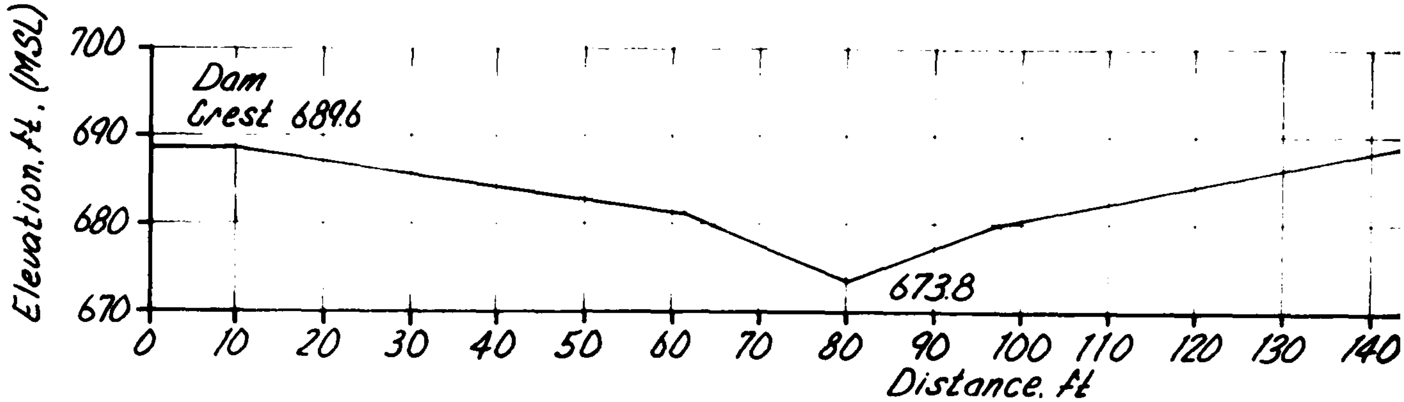



-A

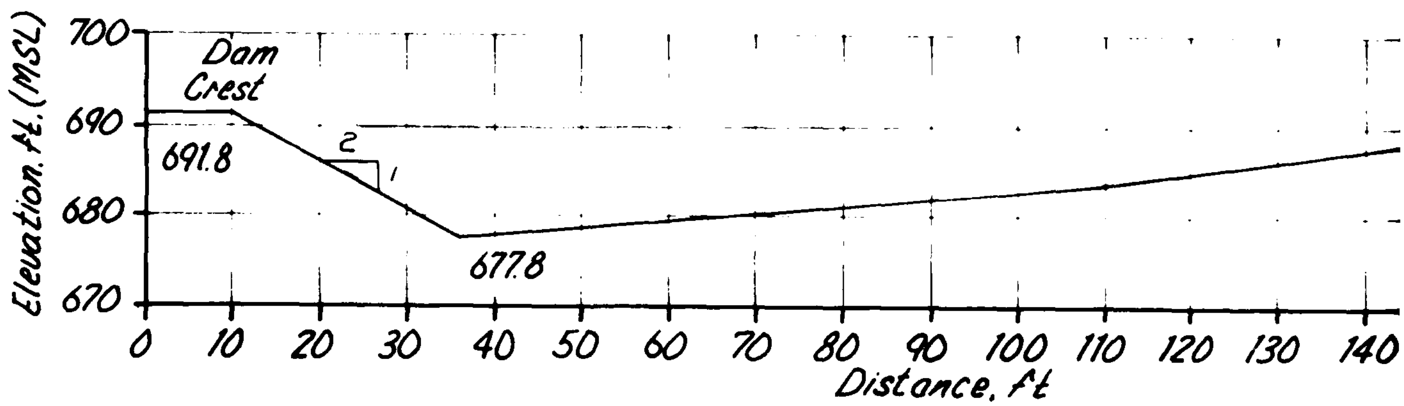
-tion

| DAM AND DISCHARGE CHANNEL SECTIONS | |
|---|---|
| WHALEY-SCOTT MINE DAM | |
| MO 31155 | Fig. 3-B |

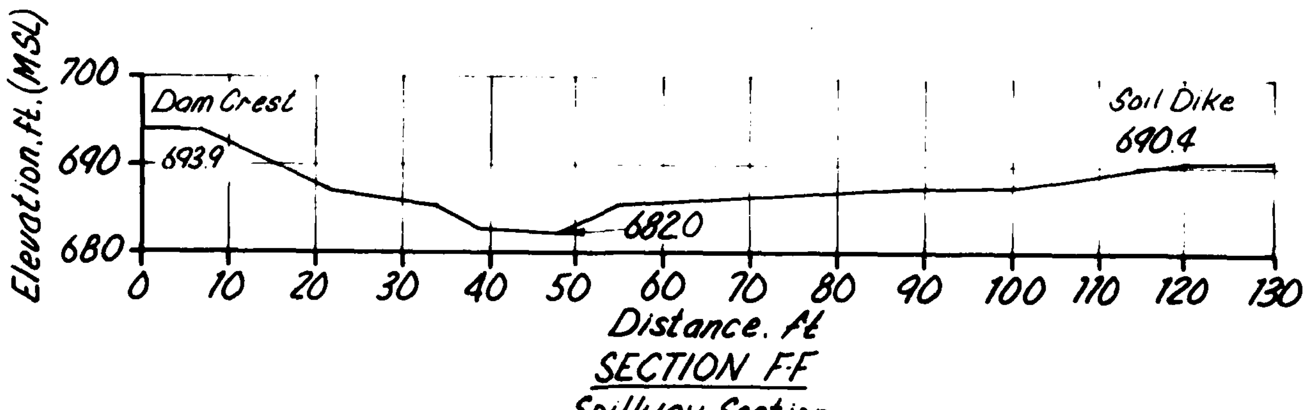
, 2



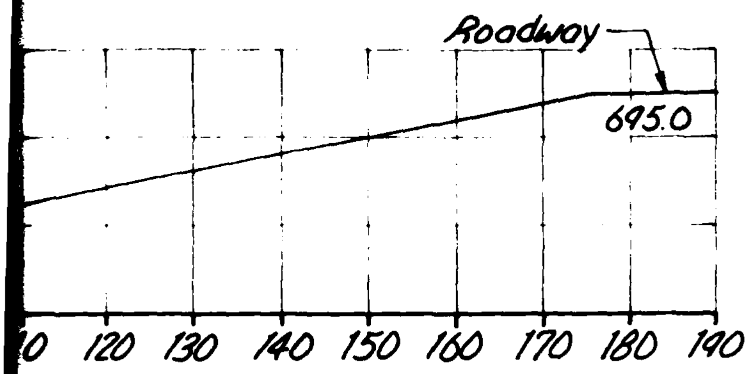

SECTION D-D
Discharge Channel



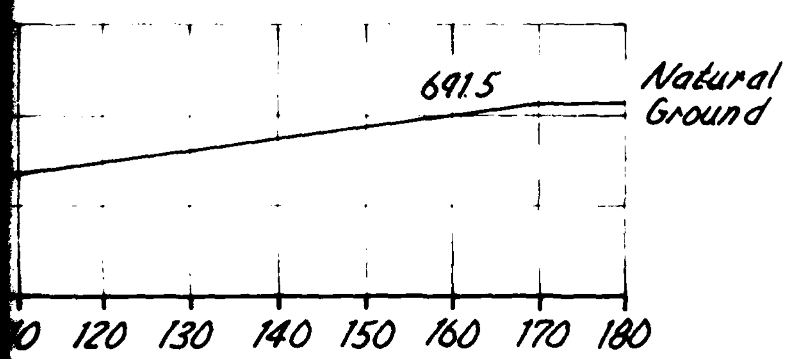

SECTION E-E
Discharge Channel

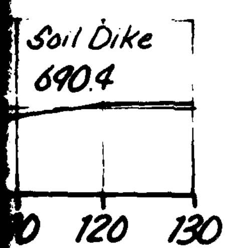



SECTION F-F
Spillway Section




el



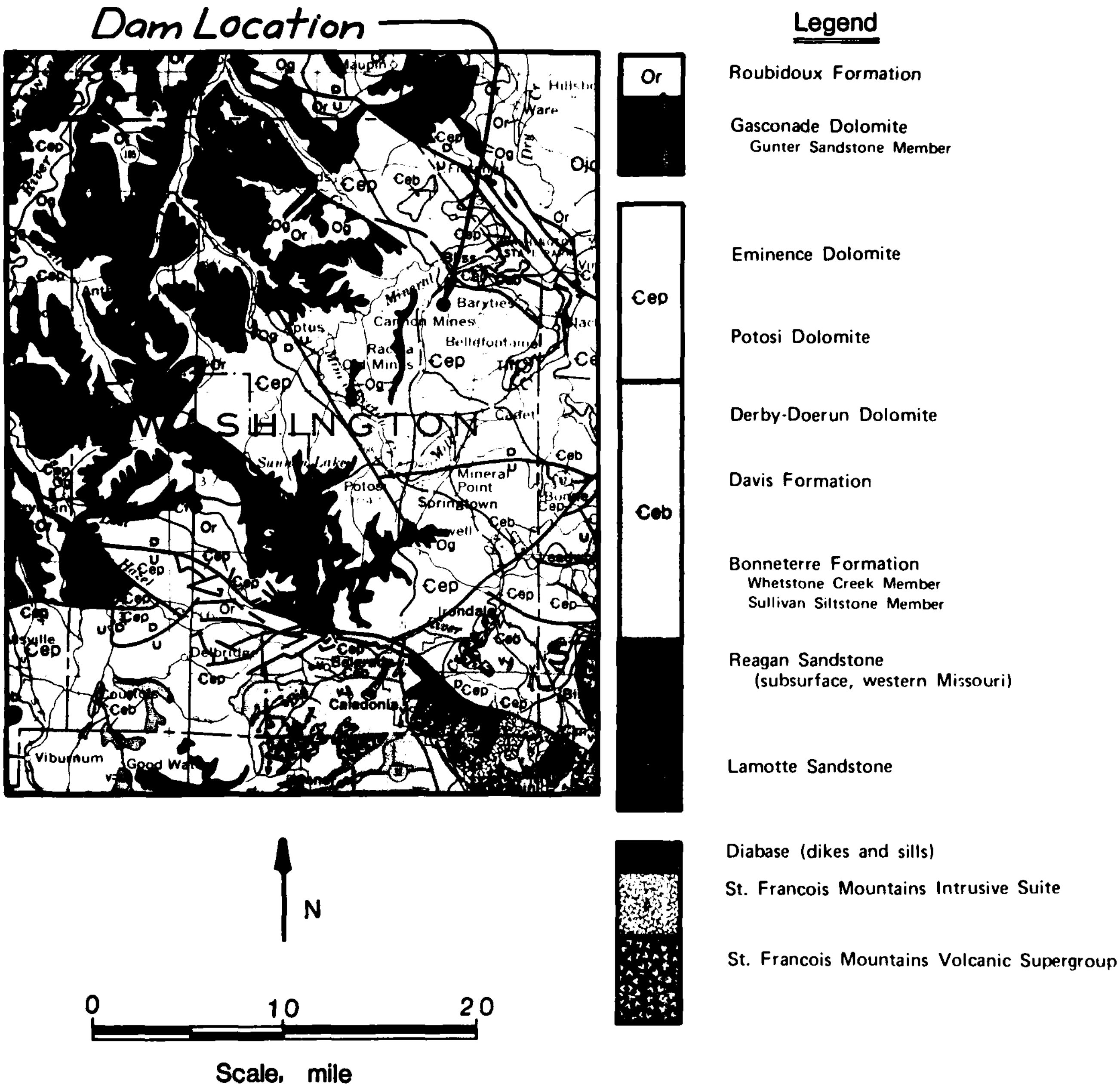




DISCHARGE CHANNEL
AND
SPILLWAY SECTIONS

WHALEY-SCOTT MINE DAM

| | |
|---|---|
| MO 31155 | Fig.3-C |

1.2




| REGIONAL GEOLOGIC MAP | |
|---|---|
| WHALEY-SCOTT MINE DAM | |
| MO 31155 | Fig. 4 |

# APPENDIX A

Photographs

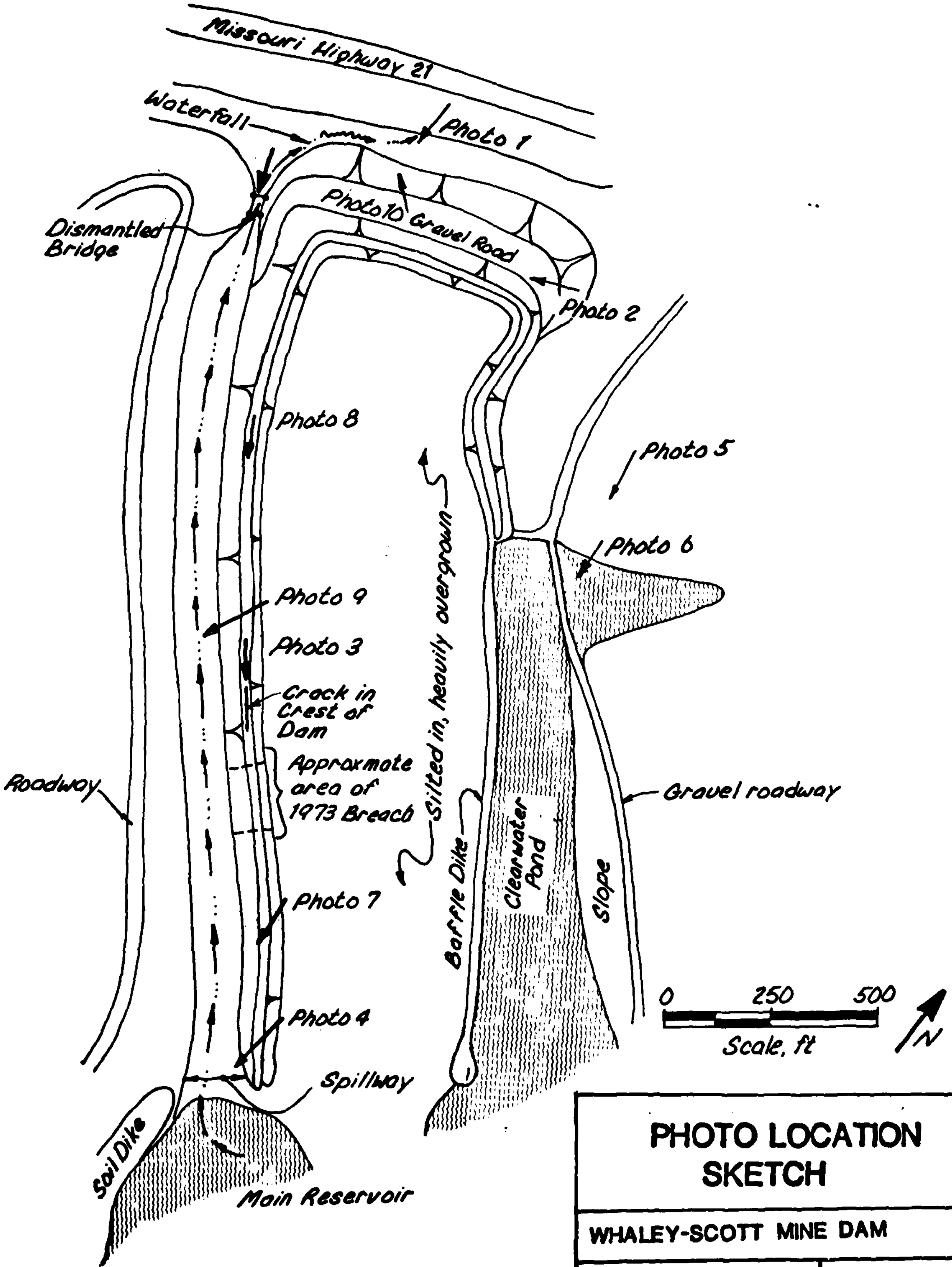
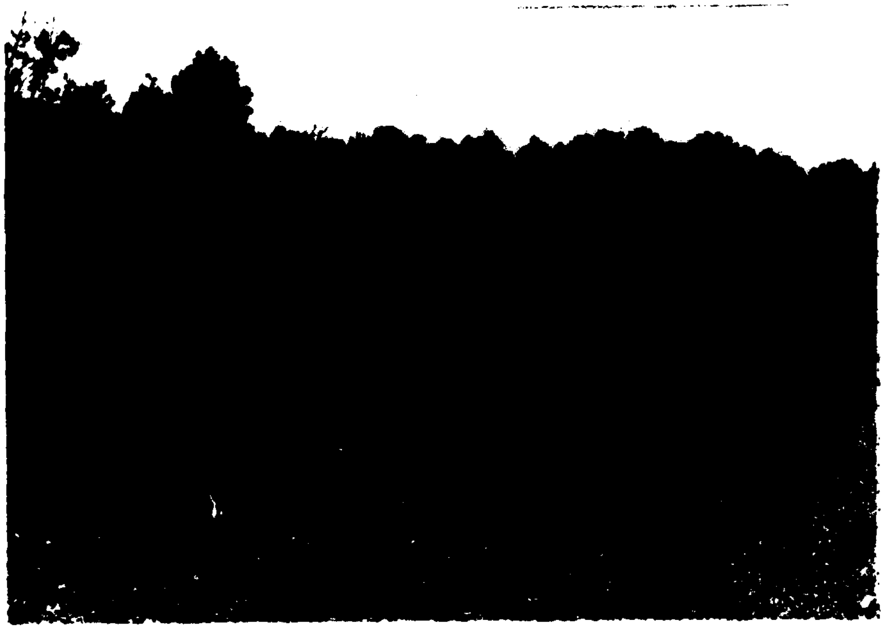



PHOTO LOCATION SKETCH

WHALEY-SCOTT MINE DAM

MO 31155 | Fig. A-1

1. Downstream face of lower tier of dam. Note discharge channel undercutting toe of slope. Looking southeast.



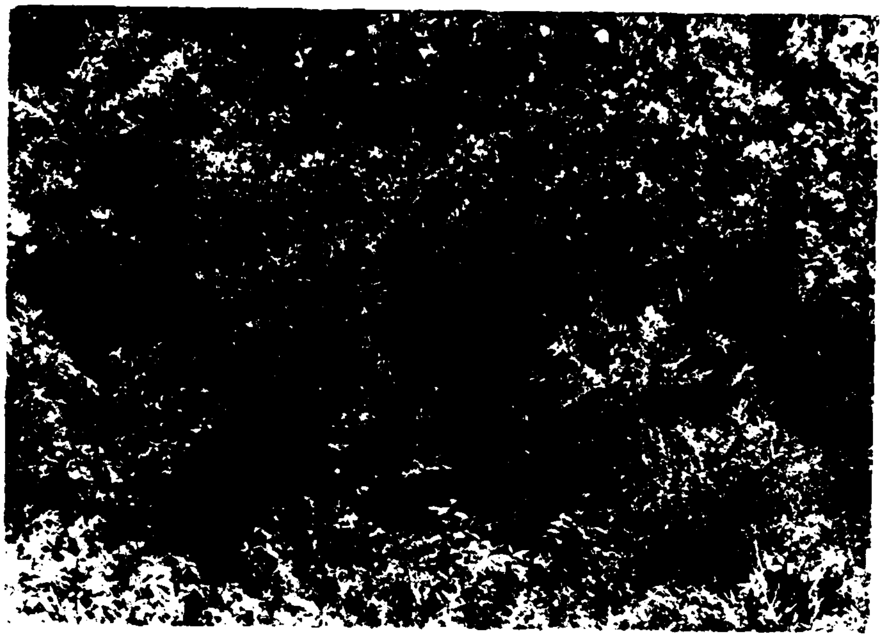
2. Downstream face of upper tier of dam. Note gravel road across face, and motorcycle tracks on embankment. Looking west.

3. Crack in dam crest near breached area. Location of former (1973) breach is in background. Impoundment is to left. Discharge channel at toe of slope to right. Maximum separation on crack approximately ½ ft vertical. Looking southeast.

4. Heavily vegetated spillway area. Channel is in foreground. Looking south from crest of embankment.

5. Heavily vegetated impoundment area. Gravel dike in foreground is northeast side of embankment. Note motorcycle tracks on dike. Southwest side of embankment and discharge channel at foot of hill in background. *Looking southwest.*

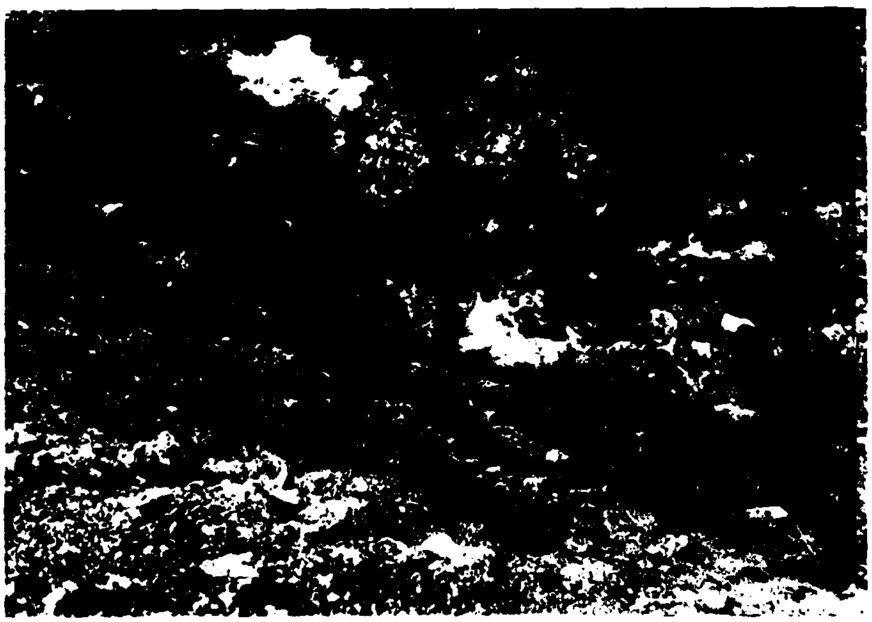
6. Clear water pond on northeast side of main impoundment. Vegetated area to right of dike is main tailings impoundment. Looking south (upstream).



7. Vegetation obstructing discharge channel. Looking southwest from crest of dam.

8. Dense vegetation at toe of embankment along discharge channel. Looking south.

9. Gravel bars in discharge channel, indicating past erosion at toe of embankment. Looking southwest from crest of embankment.



10. Falls and area of oversteepended slope near toe of maximum section. Looking northwest from crest of lower tier of dam.

11. Dismantled bridge forming constriction in discharge channel. Looking southeast, upstream.

# APPENDIX B

Hydraulic/Hydrologic Data and Analyses

## APPENDIX B
## Hydraulic/Hydrologic Data and Analyses

### B.1 Procedures

a. General. The hydraulic/hydrologic analyses were performed using the "HEC-1, Dam Safety Version (1 Apr 80)" computer program. The inflow hydrographs were developed for various precipitation events by applying them to a synthetic unit hydrograph. The inflow hydrographs were subsequently routed through the reservoir and appurtenant structures by the modified Puls reservoir routing option.

b. Precipitation events. The Probable Maximum Precipitation (PMP) and the 1 and 10 percent probability-of-occurrence events were used in the analyses. The total rainfall and corresponding distributions for the 1 and 10 percent probability events were provided by the St. Louis District, Corps of Engineers. The Probable Maximum Precipitation was determined from regional curves prepared by the US Weather Bureau (Hydrometeorological Report Number 33, 1956, reprinted 1967).

c. Unit hydrograph. The Soil Conservation Services (SCS) Dimensionless Unit Hydrograph method (National Engineering Handbook, Section 4, Hydrology, 1971) was used in the analysis. This method was selected because of its simplicity, applicability to drainage areas less than 10 mi$^2$, and its easy availability within the HEC-1 computer program.

The watershed lag time was computed using the SCS "curve number method" by an empirical relationship as follows:

$$L = \frac{\ell^{0.8}\,(s+1)^{0.7}}{1900\,Y^{0.5}} \qquad \text{(Equation 15-4)}$$

where: $L$ = lag in hours
$\ell$ = hydraulic length of the watershed in feet
$s = \frac{1000}{CN} - 10$ where CN = hydrologic soil curve number
$Y$ = average watershed land slope in percent.

This empirical relationship accounts for the soil cover, average watershed slope and hydraulic length.

With the lag time thus computed, another empirical relationship is used to compute the time of concentration as follows:

$$T_c = \frac{L}{0.6} \qquad \text{(Equation 15-3)}$$

where: $T_c$ = time of concentration in hours

L = lag in hours.

Subsequent to the computation of the time of concentration, the unit hydrograph duration was estimated utilizing the following relationship:

$$\Delta D = 0.133T_c \qquad \text{(Equation 16-12)}$$

where: $\Delta D$ = duration of unit excess rainfall
$T_c$ = time of concentration in hours.

The final interval was selected to provide at least three discharge ordinates prior to the peak discharge ordinate of the unit hydrograph. For this dam, a time interval of 20 minutes was used for the PMF analyses.

d. Infiltration losses. The infiltration losses were computed by the HEC-1 computer program internally using the SCS curve number method. The curve numbers were established taking into consideration the variables of: (a) antecedent moisture condition, (b) hydrologic soil group classification, (c) degree of development, (d) vegetative cover and (e) present land usage in the watershed.

Antecedent moisture condition III (AMC III) was used for the PMF events and AMC II was used for the 1 and 10 percent probability events, in accordance with the guidelines. The remaining variables are defined in the SCS procedure and judgements in their selection were made on the basis of visual field inspection.

e. Starting elevations. Reservoir starting water surface elevations for this dam were set as follows:

Probable Maximum Storm -spillway crest elevation of 682.0 ft.

This was based on the lack of an observable high water mark in the reservoir, and the fact that discharge through the spillway is constrained by backwater conditions in the discharge channel rather than conditions in the spillway or reservoir.

f. Spillway Rating Curve. The HEC-2 computer program was used to compute the spillway rating curve using discharge channel cross sections and conveyance characteristics.

B.2 Pertinent Data

a. Drainage area. 1.15 $mi^2$

b. Storm duration. A unit hydrograph was developed by the SCS method option of HEC-1 program. The design storm of 48 hours duration was divided into 20-minute intervals in order to develop the inflow hydrograph.

c. Lag time. 1.79 hrs.

d. Hydrologic soil group. C

e. SCS curve numbers.

1. For PMF- AMC III - Curve Number 88
2. For 1 and 10 percent probability-of-occurrence events AMC II - Curve Number 74

f. Storage. Elevation-area data were developed by planimetering areas at various elevation contours on the USGS Tiff, Missouri, 7.5-minute quadrangle map. The data were entered on the $A and $E cards so that the HEC-1 program could compute storage volumes.

g. Outflow over dam crest. As the profile of the dam crest is irregular, flow over the crest was computed according to the "Flow Over Non-Level Dam Crest" supplement to the HEC-1 User's Manual. The crest length-elevation data and hydraulic constants were entered on the $D, $L, and $V cards.

h. Outflow capacity. The spillway rating curve was developed from the cross-section data of the spillway and the downstream channel, using the HEC-2 back water program. The results of the above were entered on the Y-4 and Y-5 cards of the HEC-1 program.

i. Reservoir elevations. For the 50 and 100 percent of the PMF events and 1 and 10 percent probability events, the starting reservoir elevation was 682.0 ft, the spillway crest elevation, which is also the observed elevation of high water during the field inspection.

## B.3 Results

The results of the analyses as well as the input values to the HEC-1 program follow in this Appendix. Only the results summaries are included, not the intermediate output. Complete copies of the HEC-1 output are available in the project files.

```
**********************************
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION       JULY 1978
  LAST MODIFICATION  01 APR 80
**********************************
    1             A1     DAM NO. 30476 - WHALEY-SCOTT MINE DAM, WASHINGTON COUNTY, MISSOURI.
    2             A2     WOODWARD-CLYDE CONSULTANTS, HOUSTON JOB 79CH009.
    3             A3     PROBABLE MAXIMUM FLOODS (PMF) ANALYSIS.
    4             B    144.     0      20     -0     -0     -0     -0     -0     -0     -0
    5             B1     5
    6             J      1      4       1
    7             J1    .25    .50    .75   1.00
    8             K      0    D-IN                                     1
    9             K1   WHALEY-SCOTT MINE DAM INFLOW COMPUTATION, PMF RATIO FLOODS.
   10             M      1      2     1.15                     1.0
   11             P      0     26.     102    120    130      140
   12             T                                                  -1     .08           0.06
   13             W2           1.70
   14             X     -1    -.05      5
   15             K      1     DAM                                    1
   16             K1   WHALEY-SCOTT MINE DAM FLOOD ROUTING, PMF RATIO FLOODS.
   17             Y                              1      1
   18             Y1     1                                           -682.    -1
   19             Y4   682.   692.5   683.    684.   685.   686.   687.   688.   690.   692.
   20             Y5     0.     8.     30.    150.   310.   535.   820.  1530.  3050.  5100.
   21             $A     0.    45.     47.     53.    59.
   22             $E   630.   680.    682.   689.6   700.
   23             $$   682.
   24             $D   689.6   2.6    1.5
   25             SL     0.   190.    490.    660.   950.  1285.  1410.
   26             SV  689.6   690.   690.5   691.   691.5  692.   693.
   27             K     99
```

Note: The $A and $E cards are not correct as shown. The storage cards have been changed to reflect the topography from the 1937 Tiff 7.5-minute quadrangle for elevations below 680. See pg B5 for the correct computation of storage values. Pages B9 and B10 have been changed to reflect the correct storage values. The overtopping analysis was not affected by the change in storage values.

Input Data
Various PMF Events
Whaley-Scott Mine Dam
MO 31155

B4

```
**********************************
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION       JULY 1978
 LAST MODIFICATION  01 APR 80
**********************************

RUN  DATE: 12 DEC 80
     TIME: 13.49.16

                     DAM NO. 31155 - WHALEY-SCOTT MINE DAM, WASHINGTON COUNTY, MISSOURI.
                     WOODWARD-CLYDE CONSULTANTS, HOUSTON JOB 79CH009.
                     PROBABLE MAXIMUM FLOODS (PMF) ANALYSIS.

                                             JOB SPECIFICATION
                NO      NHR     NMIN    IDAY     IHR     IMIN    METRC    IPLT    IPRT   NSTAN
               144        0       20      -0      -0       -0       -0      -0       5      -0
                                       JOPER     NWT    LROPT    TRACE
                                           5      -0       -0       -0

  SURFACE AREA=     0.       2.       6.      12.      26.      45.      47.      53.      99.
      CAPACITY=     0.       7.      45.     133.     319.     669.     761.    1141.    1723.
     ELEVATION=   630.     640.     650.     560.     670.     680.     682.     690.     700.

                          CREL    SPWID    COQW    EXPW    ELEVL    COQL    CAREA    EXPL
                         682.0      -0.      -0.     -0.      -0.     -0.      -0.     -0.

                                                  DAM DATA
                                          TOPEL    COQD    EXPD   DAMWID
                                          689.6     2.6     1.5      -0.

PEAK OUTFLOW IS      739. AT TIME  43.00 HOURS

PEAK OUTFLOW IS     1923. AT TIME  42.33 HOURS

PEAK OUTFLOW IS     2979. AT TIME  42.00 HOURS

PEAK OUTFLOW IS     4300. AT TIME  41.67 HOURS
```

Input Data
Various PMF Events
Whaley-Scott Mine Dam
MO 31155

B5

```
RUN DATE: 3 AUG 80
TIME: 09.42.57

          DAM NO. 30476 - WHALEY-SCOTT MINE DAM, WASHINGTON COUNTY, MISSOURI.
          WOODWARD-CLYDE CONSULTANTS, HOUSTON JOB 79CH009.
          PROBABLE MAXIMUM FLOODS (PMF) ANALYSIS.

                              JOB SPECIFICATION
     NQ     NHR    NMIN    IDAY     IHR    IMIN   METRC    IPLT    IPRT   NSTAN
    144       0      20      -0      -0      -0      -0      -0      -0      -0
                           JOPER     NWT   LROPT   TRACE
                               5      -0      -0      -0

                     MULTI-PLAN ANALYSES TO BE PERFORMED
                       NPLAN= 1 NRTIO= 4 LRTIO= 1
     RTIOS=    .25    .50    .75   1.00

     *********         *********         *********         *********         *********

                         SUB-AREA RUNOFF COMPUTATION

     WHALEY-SCOTT MINE DAM INFLOW COMPUTATION, PMF RATIO FLOODS.

                 ISTAQ   ICOMP   IECON   ITAPE    JPLT    JPRT   INAME  ISTAGE   IAUTO
                  Q-IN       0      -0      -0      -0      -0       1      -0      -0

                                 HYDROGRAPH DATA
     IHYDG    IUHG   TAREA    SNAP   TRSDA   TRSPC   RATIO   ISNOW   ISAME   LOCAL
         1       2    1.15     -0.    1.15    1.00     -0.      -0      -0      -0

                                  PRECIP DATA
              SPFE     PMS      R6     R12     R24     R48     R72     R96
                0.   26.00  102.00  120.00  130.00  140.00     -0.     -0.

                                   LOSS DATA
     LROPT   STRKR   DLTKR   RTIOL   ERAIN   STRKS   RTIOK   STRTL   CNSTL   ALSMX   RTIMP
        -0     -0.     -0.    1.00     -0.     -0.    1.00   -1.00  -88.00     -0.     .06

       CURVE NO = -88.00   WETNESS =  -1.00   EFFECT CN =  88.00

                             UNIT HYDROGRAPH DATA
                          TC= -0.        LAG= 1.79

                                RECESSION DATA
                 STRTQ=    -1.00    QRCSN=    -.05    RTIOR= 5.00

     UNIT HYDROGRAPH 29 END OF PERIOD ORDINATES, TC=   -0.   HOURS, LAG=   1.79  VOL= 1.00
       23.     68.    140.    225.    273.    283.    265.    230.    182.    130.
       98.     75.     58.     43.     33.     25.     19.     14.     11.      8.
        6.      5.      4.      3.      2.      2.      1.      1.      0.

      0                                END-OF-PERIOD FLOW
   MO.DA  HR.MN  PERIOD   RAIN   EXCS   LOSS   COMP Q     MO.DA  HR.MN  PERIOD   RAIN   EXCS   LOSS   COMP Q

    1.01    .20       1    .00    .00    .00       1.      1.02    .20      73    .06    .05    .01      18.
    1.01    .40       2    .00    .00    .00       1.      1.02    .40      74    .06    .05    .01      19.
    1.01   1.00       3    .00    .00    .00       1.      1.02   1.00      75    .06    .05    .01      20.
```

Input Data
Various PMF Events
Whaley-Scott Mine Dam
MO 31155

B6

Output Summary
Various PMF Events
Whaley-Scott Mine Dam
MO 31155
B7

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| [illegible] | 66. | 150. | 225. | 273. | 243. | 265. | 230. | 182. | 130. |
| 96. | 75. | 54. | 43. | 33. | 25. | 19. | 14. | 11. | 8. |
| 6. | 5. | 4. | 3. | 2. | 2. | 1. | 1. | 0. | |

END-OF-PERIOD FLOW

| 0 MO.DA | HR.MN | PERIOD | RAIN | EXCS | LOSS | COMP Q | MO.DA | HR.MN | PERIOD | RAIN | EXCS | LOSS | COMP Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.01 | .20 | 1 | .00 | .00 | .00 | 1. | 1.02 | .20 | 73 | .06 | .05 | .01 | 16. |
| 1.01 | .40 | 2 | .00 | .00 | .00 | 1. | 1.02 | .40 | 74 | .06 | .05 | .01 | 19. |
| 1.01 | 1.00 | 3 | .00 | .00 | .00 | 1. | 1.02 | 1.00 | 75 | .06 | .05 | .01 | 24. |
| 1.01 | 1.20 | 4 | .00 | .00 | .00 | 1. | 1.02 | 1.20 | 76 | .06 | .05 | .01 | 34. |
| 1.01 | 1.40 | 5 | .00 | .00 | .00 | 1. | 1.02 | 1.40 | 77 | .06 | .05 | .01 | 46. |
| 1.01 | 2.00 | 6 | .00 | .00 | .00 | 1. | 1.02 | 2.00 | 78 | .06 | .05 | .01 | [illegible] |
| 1.01 | 2.20 | 7 | .00 | .00 | .00 | 1. | 1.02 | 2.20 | 79 | .06 | .05 | .01 | 71. |
| 1.01 | 2.40 | 8 | .00 | .00 | .00 | 1. | 1.02 | 2.40 | 80 | .06 | .05 | .01 | 81. |
| 1.01 | 3.00 | 9 | .00 | .00 | .00 | 1. | 1.02 | 3.00 | 81 | .06 | .05 | .01 | 89. |
| 1.01 | 3.20 | 10 | .00 | .00 | .00 | 1. | 1.02 | 3.20 | 82 | .06 | .05 | .01 | 96. |
| 1.01 | 3.40 | 11 | .00 | .00 | .00 | 1. | 1.02 | 3.40 | 83 | .06 | .05 | .01 | 100. |
| 1.01 | 4.00 | 12 | .00 | .00 | .00 | 1. | 1.02 | 4.00 | 84 | .06 | .05 | .01 | 104. |
| 1.01 | 4.20 | 13 | .00 | .00 | .00 | 1. | 1.02 | 4.20 | 85 | .06 | .05 | .01 | 107. |
| 1.01 | 4.40 | 14 | .00 | .00 | .00 | 1. | 1.02 | 4.40 | 86 | .06 | .05 | .01 | 109. |
| 1.01 | 5.00 | 15 | .00 | .00 | .00 | 1. | 1.02 | 5.00 | 87 | .06 | .05 | .00 | 111. |
| 1.01 | 5.20 | 16 | .00 | .00 | .00 | 1. | 1.02 | 5.20 | 88 | .06 | .05 | .00 | 112. |
| 1.01 | 5.40 | 17 | .00 | .00 | .00 | 1. | 1.02 | 5.40 | 89 | .06 | .05 | .00 | 114. |
| 1.01 | 6.00 | 18 | .00 | .00 | .00 | 1. | 1.02 | 6.00 | 90 | .06 | .05 | .00 | 117. |
| 1.01 | 6.20 | 19 | .02 | .00 | .02 | 1. | 1.02 | 6.20 | 91 | .26 | .24 | .02 | 120. |
| 1.01 | 6.40 | 20 | .02 | .00 | .02 | 1. | 1.02 | 6.40 | 92 | .26 | .24 | .02 | 133. |
| 1.01 | 7.00 | 21 | .02 | .00 | .02 | 1. | 1.02 | 7.00 | 93 | .26 | .24 | .02 | 166. |
| 1.01 | 7.20 | 22 | .02 | .00 | .02 | 1. | 1.02 | 7.20 | 94 | .26 | .25 | .01 | 203. |
| 1.01 | 7.40 | 23 | .02 | .00 | .02 | 1. | 1.02 | 7.40 | 95 | .26 | .25 | .01 | 255. |
| 1.01 | 8.00 | 24 | .02 | .00 | .02 | 2. | 1.02 | 8.00 | 96 | .26 | .25 | .01 | 310. |
| 1.01 | 8.20 | 25 | .02 | .00 | .02 | 2. | 1.02 | 8.20 | 97 | .26 | .25 | .01 | 361. |
| 1.01 | 8.40 | 26 | .02 | .00 | .02 | 2. | 1.02 | 8.40 | 98 | .26 | .25 | .01 | 407. |
| 1.01 | 9.00 | 27 | .02 | .00 | .02 | 2. | 1.02 | 9.00 | 99 | .26 | .25 | .01 | 443. |
| 1.01 | 9.20 | 28 | .02 | .00 | .02 | 2. | 1.02 | 9.20 | 100 | .26 | .25 | .01 | 465. |
| 1.01 | 9.40 | 29 | .02 | .00 | .02 | 2. | 1.02 | 9.40 | 101 | .26 | .25 | .01 | 490. |
| 1.01 | 10.00 | 30 | .02 | .00 | .02 | 3. | 1.02 | 10.00 | 102 | .26 | .25 | .01 | 506. |
| 1.01 | 10.20 | 31 | .02 | .00 | .02 | 3. | 1.02 | 10.20 | 103 | .26 | .25 | .01 | 519. |
| 1.01 | 10.40 | 32 | .02 | .00 | .02 | 3. | 1.02 | 10.40 | 104 | .26 | .25 | .01 | 529. |
| 1.01 | 11.00 | 33 | .02 | .00 | .02 | 3. | 1.02 | 11.00 | 105 | .26 | .25 | .01 | 537. |
| 1.01 | 11.20 | 34 | .02 | .00 | .02 | 4. | 1.02 | 11.20 | 106 | .26 | .25 | .01 | 543. |
| 1.01 | 11.40 | 35 | .02 | .00 | .02 | 4. | 1.02 | 11.40 | 107 | .26 | .25 | .01 | 548. |
| 1.01 | 12.00 | 36 | .02 | .00 | .02 | 5. | 1.02 | 12.00 | 108 | .26 | .25 | .01 | 552. |
| 1.01 | 12.20 | 37 | .07 | .02 | .05 | 6. | 1.02 | 12.20 | 109 | .89 | .87 | .02 | 569. |
| 1.01 | 12.40 | 38 | .07 | .02 | .04 | 8. | 1.02 | 12.40 | 110 | .88 | .87 | .01 | 613. |
| 1.01 | 13.00 | 39 | .07 | .03 | .04 | 11. | 1.02 | 13.00 | 111 | .88 | .87 | .01 | 701. |
| 1.01 | 13.20 | 40 | .09 | .04 | .05 | 16. | 1.02 | 13.20 | 112 | 1.06 | 1.05 | .01 | 849. |
| 1.01 | 13.40 | 41 | .08 | .04 | .04 | 23. | 1.02 | 13.40 | 113 | 1.06 | 1.05 | .01 | 1027. |
| 1.01 | 14.00 | 42 | .08 | .04 | .04 | 31. | 1.02 | 14.00 | 114 | 1.06 | 1.05 | .01 | 1228. |
| 1.01 | 14.20 | 43 | .10 | .06 | .04 | 41. | 1.02 | 14.20 | 115 | 1.33 | 1.32 | .01 | 1438. |
| 1.01 | 14.40 | 44 | .10 | .06 | .04 | 51. | 1.02 | 14.40 | 116 | 1.33 | 1.32 | .01 | 1648. |
| 1.01 | 15.00 | 45 | .10 | .07 | .04 | 63. | 1.02 | 15.00 | 117 | 1.33 | 1.32 | .01 | 1849. |
| 1.01 | 15.20 | 46 | .15 | .12 | .06 | 77. | 1.02 | 15.20 | 118 | 2.32 | 2.31 | .01 | 2060. |
| 1.01 | 15.40 | 47 | .49 | .37 | .12 | 98. | 1.02 | 15.40 | 119 | 6.35 | 6.33 | .02 | 2393. |
| 1.01 | 16.00 | 48 | .11 | .09 | .02 | 129. | 1.02 | 16.00 | 120 | 1.41 | 1.41 | .00 | 2888. |
| 1.01 | 16.20 | 49 | .10 | .08 | .02 | 157. | 1.02 | 16.20 | 121 | 1.24 | 1.24 | .00 | 3423. |
| 1.01 | 16.40 | 50 | .10 | .08 | .02 | 207. | 1.02 | 16.40 | 122 | 1.24 | 1.24 | .00 | 4004. |
| 1.01 | 17.00 | 51 | .10 | .08 | .02 | 232. | 1.02 | 17.00 | 123 | 1.24 | 1.24 | .00 | 4339. |
| 1.01 | 17.20 | 52 | .07 | .06 | .01 | 243. | 1.02 | 17.20 | 124 | .97 | .97 | .00 | 4411. |
| 1.01 | 17.40 | 53 | .07 | .05 | .01 | 243. | 1.02 | 17.40 | 125 | .97 | .97 | .00 | 4252. |
| 1.01 | 18.00 | 54 | .07 | .06 | .01 | 233. | 1.02 | 18.00 | 126 | .97 | .97 | .00 | 4035. |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.01 | 11.20 | 34 | .02 | .00 | .02 | 4. | 1.02 | 11.20 | 106 | .26 | .25 | .01 | 543. |
| 1.01 | 11.40 | 35 | .02 | .00 | .02 | 4. | 1.02 | 11.40 | 107 | .26 | .25 | .01 | 548. |
| 1.01 | 12.00 | 36 | .02 | .00 | .02 | 5. | 1.02 | 12.00 | 108 | .26 | .25 | .01 | 552. |
| 1.01 | 12.20 | 37 | .07 | .02 | .05 | 6. | 1.02 | 12.20 | 109 | .89 | .87 | .02 | 569. |
| 1.01 | 12.40 | 38 | .07 | .02 | .04 | 8. | 1.02 | 12.40 | 110 | .88 | .87 | .01 | 613. |
| 1.01 | 13.00 | 39 | .07 | .03 | .04 | 11. | 1.02 | 13.00 | 111 | .88 | .87 | .01 | 701. |
| 1.01 | 13.20 | 40 | .08 | .04 | .05 | 16. | 1.02 | 13.20 | 112 | 1.06 | 1.05 | .01 | 845. |
| 1.01 | 13.40 | 41 | .08 | .04 | .04 | 23. | 1.02 | 13.40 | 113 | 1.06 | 1.05 | .01 | 1027. |
| 1.01 | 14.00 | 42 | .08 | .04 | .04 | 31. | 1.02 | 14.00 | 114 | 1.06 | 1.05 | .01 | 1228. |
| 1.01 | 14.20 | 43 | .10 | .06 | .04 | 41. | 1.02 | 14.20 | 115 | 1.33 | 1.32 | .01 | 1438. |
| 1.01 | 14.40 | 44 | .10 | .05 | .04 | 51. | 1.02 | 14.40 | 116 | 1.33 | 1.32 | .01 | 1648. |
| 1.01 | 15.00 | 45 | .10 | .07 | .04 | 63. | 1.02 | 15.00 | 117 | 1.33 | 1.32 | .01 | 1849. |
| 1.01 | 15.20 | 46 | .19 | .12 | .06 | 77. | 1.02 | 15.20 | 118 | 2.32 | 2.31 | .01 | 2060. |
| 1.01 | 15.40 | 47 | .49 | .37 | .12 | 98. | 1.02 | 15.40 | 119 | 6.35 | 6.33 | .02 | 2393. |
| 1.01 | 16.00 | 48 | .11 | .09 | .02 | 129. | 1.02 | 16.00 | 120 | 1.41 | 1.41 | .00 | 2848. |
| 1.01 | 16.20 | 49 | .10 | .08 | .02 | 167. | 1.02 | 16.20 | 121 | 1.24 | 1.24 | .00 | 3423. |
| 1.01 | 16.40 | 50 | .10 | .08 | .02 | 207. | 1.02 | 16.40 | 122 | 1.24 | 1.24 | .00 | 4004. |
| 1.01 | 17.00 | 51 | .10 | .08 | .02 | 232. | 1.02 | 17.00 | 123 | 1.24 | 1.24 | .00 | 4338. |
| 1.01 | 17.20 | 52 | .07 | .06 | .01 | 243. | 1.02 | 17.20 | 124 | .97 | .97 | .00 | 4411. |
| 1.01 | 17.40 | 53 | .07 | .06 | .01 | 243. | 1.02 | 17.40 | 125 | .97 | .97 | .00 | 4252. |
| 1.01 | 18.00 | 54 | .07 | .06 | .01 | 233. | 1.02 | 18.00 | 126 | .97 | .97 | .00 | 4039. |
| 1.01 | 18.20 | 55 | .01 | .01 | .00 | 216. | 1.02 | 18.20 | 127 | .09 | .09 | .00 | 3668. |
| 1.01 | 18.40 | 56 | .01 | .01 | .00 | 194. | 1.02 | 18.40 | 128 | .09 | .09 | .00 | 3241. |
| 1.01 | 19.00 | 57 | .01 | .01 | .00 | 173. | 1.02 | 19.00 | 129 | .09 | .09 | .00 | 2856. |
| 1.01 | 19.20 | 58 | .01 | .01 | .00 | 150. | 1.02 | 19.20 | 130 | .09 | .09 | .00 | 2452. |
| 1.01 | 19.40 | 59 | .01 | .01 | .00 | 126. | 1.02 | 19.40 | 131 | .09 | .09 | .00 | 2046. |
| 1.01 | 20.00 | 60 | .01 | .01 | .00 | 103. | 1.02 | 20.00 | 132 | .09 | .09 | .00 | 1663. |
| 1.01 | 20.20 | 61 | .01 | .01 | .00 | 83. | 1.02 | 20.20 | 133 | .09 | .09 | .00 | 1335. |
| 1.01 | 20.40 | 62 | .01 | .01 | .00 | 66. | 1.02 | 20.40 | 134 | .09 | .09 | .00 | 1059. |
| 1.01 | 21.00 | 63 | .01 | .01 | .00 | 53. | 1.02 | 21.00 | 135 | .09 | .09 | .00 | 842. |
| 1.01 | 21.20 | 64 | .01 | .01 | .00 | 43. | 1.02 | 21.20 | 136 | .09 | .09 | .00 | 689. |
| 1.01 | 21.40 | 65 | .01 | .01 | .00 | 36. | 1.02 | 21.40 | 137 | .09 | .09 | .00 | 566. |
| 1.01 | 22.00 | 66 | .01 | .01 | .00 | 30. | 1.02 | 22.00 | 138 | .09 | .09 | .00 | 476. |
| 1.01 | 22.20 | 67 | .01 | .01 | .00 | 26. | 1.02 | 22.20 | 139 | .09 | .09 | .00 | 407. |
| 1.01 | 22.40 | 68 | .01 | .01 | .00 | 23. | 1.02 | 22.40 | 140 | .09 | .09 | .00 | 354. |
| 1.01 | 23.00 | 69 | .01 | .01 | .00 | 20. | 1.02 | 23.00 | 141 | .09 | .09 | .00 | 310. |
| 1.01 | 23.20 | 70 | .01 | .01 | .00 | 19. | 1.02 | 23.20 | 142 | .09 | .09 | .00 | 289. |
| 1.01 | 23.40 | 71 | .01 | .01 | .00 | 17. | 1.02 | 23.40 | 143 | .09 | .09 | .00 | 262. |
| 1.02 | 0. | 72 | .01 | .01 | .00 | 16. | 1.03 | 0. | 144 | .09 | .09 | .00 | 243. |
| | | | | | | | | | SUM | 36.40 | 34.91 | 1.49 | 76388. |
| | | | | | | | | | | ( 925.)( | 887.)( | 38.)( | 2163.79) |

| | PEAK | 6-HOUR | 24-HOUR | 72-HOUR | TOTAL VOLUME |
|---|---|---|---|---|---|
| CFS | 4411. | 2923. | 1012. | 529. | 76192. |
| CMS | 125. | 83. | 29. | 15. | 2157. |
| INCHES | | 23.65 | 32.74 | 34.24 | 34.24 |
| MM | | [illegible] | 831.65 | 869.57 | 869.57 |
| AC-FT | | 1449. | 2007. | 2099. | 2099. |
| THOUS CU M | | 1788. | 2476. | 2589. | 2589. |

HYDROGRAPH AT STA 0-IN FOR PLAN 1, RTIO 1

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 0. | 0. | 0. | 0. | 0. | 1. | 1. | 1. | 1. | 1. |
| 1. | 1. | 1. | 1. | 1. | 1. | 2. | 2. | 3. | 4. |
| 6. | 8. | 10. | 13. | 16. | 19. | 25. | 32. | 42. | 52. |
| [illegible] | 61. | [illegible] | [illegible] | 54. | [illegible] | 43. | 38. | 37. | 76. |
| 21. | 17. | 13. | 11. | 9. | 8. | 7. | 6. | 5. | 5. |
| | | | | | | | | | 20. |

Output Summary
Various PMF Events
Whaley-Scott Mine Dam
MO 31155
B8

PEAK FLOW AND STORAGE (END OF PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS
FLOWS IN CUBIC FEET PER SECOND (CUBIC METERS PER SECOND)
AREA IN SQUARE MILES (SQUARE KILOMETERS)

| OPERATION | STATION | AREA | PLAN | RATIO 1 .25 | RATIO 2 .50 | RATIO 3 .75 | RATIO 4 1.00 |
|---|---|---|---|---|---|---|---|
| | | | | RATIOS APPLIED TO FLOWS | | | |
| HYDROGRAPH AT | O-IN | 1.15 | 1 | 1103. | 2205. | 3308. | 4411. |
| | ( | 2.98) | ( | 31.23)( | 62.45)( | 93.68)( | 124.90)( |
| ROUTED TO | DAM | 1.15 | 1 | 739. | 1923. | 2979. | 4300. |
| | ( | 2.98) | ( | 20.92)( | 54.45)( | 84.37)( | 121.76)( |

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1 ...............

| | INITIAL VALUE | SPILLWAY CREST | TOP OF DAM |
|---|---|---|---|
| ELEVATION | 682.00 | 682.00 | 689.60 |
| STORAGE | 761. | 761. | 1141. |
| OUTFLOW | 0. | 0. | 2746. |

| RATIO OF PMF | MAXIMUM RESERVOIR W.S.ELEV | MAXIMUM DEPTH OVER DAM | MAXIMUM STORAGE AC-FT | MAXIMUM OUTFLOW CFS | DURATION OVER TOP HOURS | TIME OF MAX OUTFLOW HOURS | TIME OF FAILURE HOURS |
|---|---|---|---|---|---|---|---|
| .25 | 686.71 | 0. | 992. | 739. | 0. | 43.00 | 0. |
| .50 | 688.52 | 0. | 1094. | 1923. | 0. | 42.33 | 0. |
| .75 | 689.98 | .29 | 1156. | 2979. | 1.33 | 42.00 | 0. |
| 1.00 | 690.61 | 1.01 | 1195. | 4300. | 3.00 | 41.67 | 0. |

Output Summary
Various PMF Events
Whaley-Scott Mine Dam
MO 31155

B9

PEAK FLOW AND STORAGE (END OF PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS
FLOWS IN CUBIC FEET PER SECOND (CUBIC METERS PER SECOND)
AREA IN SQUARE MILES (SQUARE KILOMETERS)

| | | | | RATIOS APPLIED TO FLOWS | | |
|---|---|---|---|---|---|---|
| OPERATION | STATION | AREA | PLAN | RATIO 1 .69 | RATIO 2 .70 | RATIO 3 .71 |
| HYDROGRAPH AT | O-IN | 1.15 | 1 | 3044. | 3088. | 3132. |
| | ( | 2.98) | ( | 86.18)( | 87.43)( | 88.68)( |
| ROUTED TO | DAM | 1.15 | 1 | 2720. | 2760. | 2801. |
| | ( | 2.98) | ( | 77.01)( | 78.17)( | 79.33)( |

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1 ................

| | INITIAL VALUE | SPILLWAY CREST | TOP OF DAM |
|---|---|---|---|
| ELEVATION | 692.00 | 682.00 | 689.60 |
| STORAGE | 761. | 761. | 1141. |
| OUTFLOW | 0. | 0. | 2746. |

| RATIO OF PMF | MAXIMUM RESERVOIR W.S.ELEV | MAXIMUM DEPTH OVER DAM | MAXIMUM STORAGE AC-FT | MAXIMUM OUTFLOW CFS | DURATION OVER TOP HOURS | TIME OF MAX OUTFLOW HOURS | TIME OF FAILURE HOURS |
|---|---|---|---|---|---|---|---|
| .69 | 689.57 | 0. | 1220. | 2720. | 0. | 42.00 | 0. |
| .70 | 689.62 | .02 | 1223. | 2760. | .33 | 42.00 | 0. |
| .71 | 689.67 | .07 | 1226. | 2801. | .67 | 42.00 | 0. |

Output Summary
Various PMF Events
Whaley-Scott Mine Dam
MO 31155

B10